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Cultivated and wild host plants associated with fruit flies (Diptera: Tephritidae) in three ecological zones of Togo

Mondjonnesso GOMINA[1,3*], Atti TCHABI[1], Nafadjara Abouwaliou NADIO[1], Agbéko Kodjo TOUNOU[2], Isabelle Adolé GLITHO[3] and Komla SANDA[1]

[1]Centre d'Excellence en Protection Durable des Cultures, Université de Kara; BP: 404 Kara, Togo.
[2]Laboratoire de Recherche sur les Agroressources et la Santé Environnementale, Ecole Supérieure d'Agronomie, Université de Lomé; BP: 1515 Lomé, Togo.
[3]Laboratoire d'Entomologie Appliquée, Faculté des Sciences, Université de Lomé; BP: 1515 Lomé, Lomé, Togo.
[*]Corresponding author; E-mail: gominadjo@gmail.com; Tel.: (00228) 91 85 65 08).

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ABSTRACT

Fruit flies are a major constraint on the production and marketing of fruits and vegetables in Togo. It is important to master the bioecology of fruits flies before setting up a method for managing their populations effectively, sustainably, at low cost and with regard for environment health. In this context, this study was carried out to evaluate interaction between fruit flies and their respective host plants. Fruits and vegetables were sampled in 2019 in ecological zones III, IV and V in Togo. Fruits and vegetables incubation allowed to identify 15 host plants associated with 8 species of fruit flies belonging to the genera *Bactrocera*, *Ceratitis*, *Dacus* and *Zeugodacus*. B*actrocera dorsalis* (Hendel) and *Ceratitis cosyra* (Walker) were the most abundant with respectively 47.51 and 46.03% of the 6858 flies recovered. The infestation rate of the mango by *B. dorsalis* ranged from 1.93 to 70.83 flies/kg of fruit. Among the 7 host plants associated with *B. dorsalis*, the mango was the most infested cultivated fruit and the African apple the most infested wild fruit ($F = 3.077$, $df = 6$, $p = 0.008$). This study expands the available database on the interactions between fruit flies and their hosts in Togo.

Keywords: fruits, vegetables, incubation, mango, infestation rate, *Bactrocera dorsalis*

INTRODUCTION

The fruit and vegetable sectors being an integral part of the horticultural sector, provide income to producers and therefore promote poverty reduction in sub-Saharan Africa (Vayssières et al., 2014; Parrot et al., 2018). In 2012, exports of fruits and vegetables by the West African Economic and Monetary Union (UEMOA) countries generated US$ 434.144 million (Galibaka, 2015). In Togo, out of a production of around 560,000 tons of these foodstuff in 2017, exports were estimated at 30,265 tons valued at 4.578 billion FCFA (FAO, 2019). Unfortunately, this production and export are threatened because fruit and vegetable plants are attacked by fruit flies (Diptera: Tephritidae) such us *Dacus ciliatus* Loew, *Zeugodacus cucurbitae* (Coquillett), *Ceratitis capitata* (Wiedemann), *Ceratitis cosyra* (Walker) and especially *Bactrocera*

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dorsalis (Hendel) which in recent years has been the most economically destructive fly in West Africa. This species is associated with mangoes and citrus (Zida et al., 2020; Amevoin et al., 2021; Mutamiswa et al., 2021). The infestation rate of fruits and vegetables depending on the locality and season varies between 5 and 100% (Lux et al., 2003). In the European Union countries, infestations cause the interception of fruits and vegetables from West African countries (Benin, Burkina Faso, Côte d'Ivoire, Gambia, Ghana, Mali, Senegal, Togo) (Parrot et al., 2018; Europhyt, 2022). The infestation of fruits and vegetables by fruit flies, which are quarantine insects, is therefore considered the main constraint on the production and export of these foodstuff produced in Africa (Ekesi et al., 2016). Faced with this situation, studies on the bio-ecology and ethology of these pests have been carried out (Mwatawala et al., 2006; Ekesi et al., 2009; Vayssières et al., 2009, 2014; Konta et al., 2015; Sanou et al., 2019; Zida et al., 2020). This results of these multiple studies have been the basis for reasoned and sound environmentally friendly control efforts that have been made to achieve a sustainable and efficient management of the populations of fruit and vegetable pest in general and of *B. dorsalis* in particular. This multiple studies were based on the use of biological insecticides such as GF-120 and *Metarhizium acridum* (Driver & Milner) J.F. Bisch., S.A. Rehner and Humber (Ekesi et al., 2011; Faye et al., 2021), predators such as *Oecophylla longinoda* Latreille (Van Mele et al., 2007) and parasitoids like *Fopius arisanus* Sonan (Gnanvossou et al., 2016). Despite these different control methods, these economically destructive flies are still the major constraint on the production and export of fruits and vegetables from tropical and sub-tropical regions.

In Togo, except the work carried out by Gomina et al. (2012, 2014, 2020) and Amevoin et al. (2009, 2021), very few studies on the bio-ecological parameters of fruit flies have been done. To fill this gap, the "ProMangue" project was initiated to enlarge the existing database on fruit fly bio-ecology and use this database in the long term to adapt to the national context a sustainable method for managing the populations of these Tephritidae associated with fruits in general and the mango in particular in orchards. Thus, to contribute to the achievement of these aforementioned objectives, it is important to continue the surveys initiated by the authors cited above throughout Togo in order to widen the database on the bio-ecology and the ethology of fruit flies in general and those that have an economic importance in particular through the mastery of the tri-trophic system "Plants-Tephritidae-Parasitoids". It is in this context that this study was carried out. The objective of this study was to assess interaction between fruit flies and their host plants in ecological zones III, IV and V.

MATERIALS AND METHODS

Study area

The study was carried out in ecological zones III, IV and V (Figure 1) defined by Ern (1979). Ecological zone III extended over the all central plain with vegetation consisting of Guinean savannahs interspersed with vast expanses of dry forests. It was characterized by a lowland Guinean climate marked by a rainy season (April to October) and a dry season (November to March). The average monthly temperatures ranged from 26 to 30°C and the average annual precipitation oscillated around 1200 mm. Ecological zone IV corresponded to the southern part of the Togo Mountains and constitutes a forest zone in Togo. The climate in this zone was of the subequatorial type and was marked by a rainy season (March-November) and a dry season (December-February). The average monthly temperatures varied between 21 and 26°C. The Average annual rainfall was around 1800 mm. Compared to ecological zones III and IV, ecological zone V was a highly anthropized savannah with forest islands. This zone had a Guinean tropical climate characterized by two rainy seasons (April-July and September-October) and two dry seasons (August and November-March). Average monthly

temperatures ranged from 26 to 30°C. Average annual rainfall was around 932 mm.

These three zone were chosen for their agro-ecological contrast and the diversity of their production of potential host plants for fruit flies. Fruits and vegetables were sampled in 53 localities including 14, 12 and 27 respectively in ecological zones III, IV and V (Figure 1).

Fruits and vegetables sampling

Fruits and vegetables at the prematurity and maturity stages were sampled during their availability period, in the fields, in and around the mango orchards, and around dwellings every two weeks (Table 1). These fruits and vegetables were picked from the branches of trees and shrubs, and from lianas and herbaceous plants. Only the fruits of *Vitex doniana* Sweet and *Spondias mombin* Jacq. were picked from the ground because the trees of these plants are very tall. Sampling in the study zone was done from May to July 2019. Mango samples were taken in May and June. The other fruits and vegetables were sampled in July only.

Incubation of fruits and vegetables

The sampled fruits and vegetables were incubated in the laboratory at 27.5 ± 1°C and 79.5 ± 3% relative Humidity. The fruit and vegetable samples were weighed and kept under observation in cylindrical transparent plastic pots containing sterilized and moistened sand. The pots measuring 16.5 cm in diameter and 16 cm in height, were labeled. In each pot, the sand was topped with a grid on which various fruits were placed. The pot was then covered with muslin in order to prevent the escape of emerged larvae. The sand was sifted weekly to recover fruit fly puparia. The puparia were transferred to rearing cages and monitored until adult flies emerge. Emerged Tephritidae adults were recovered and stored inside vials containing 70° alcohol for identification.

Identification of Tephritidae species

The species of Tephritidae recovered during fruit incubation were sorted and identified in the Laboratory of Applied Entomology (LEA) of the University of Lomé using the CD-ROM of reference works for Africa (White, 2006), the determination keys developed by De Meyer and White (2008) and Virgilio et al. (2014).

Statistical analysis

The infestation rate of a fruit by a species of fruit fly was calculated as the number of flies per kg of the incubated fruit (Zida et al., 2020). The similarity between the different ecological zones surveyed (taken two by two) in terms of the specific diversity of fruit flies was evaluated using the Sorensen index (S_i): $S_i = \frac{2a}{b+c}$; where a = number of species common to the two zones considered, b = species richness in the first study zone and c = species richness in the second study zone (Magurran, 1988). There is similarity between two compared zones if the S_i is greater than or equal to 0.5.

In order to stabilize the variance and normalize the data, infestation rate of fruit by fruit flies identified in the different ecological zones was transformed using the formula : $\sqrt{x+1}$ (were x = the infestation rate of a fruit by a fruit fly). The comparison of the means was performed by the analysis of variance (ANOVA-1) followed by the LSD test at the 5% threshold using the SPSS-20 software to determine the host plants most infested by *B. dorsalis*. Similarly, principal component analysis (PCA) was performed on the transformed data to assess the level of interaction between the host plants and the tephritids emerged from them using the Past4.03 software.

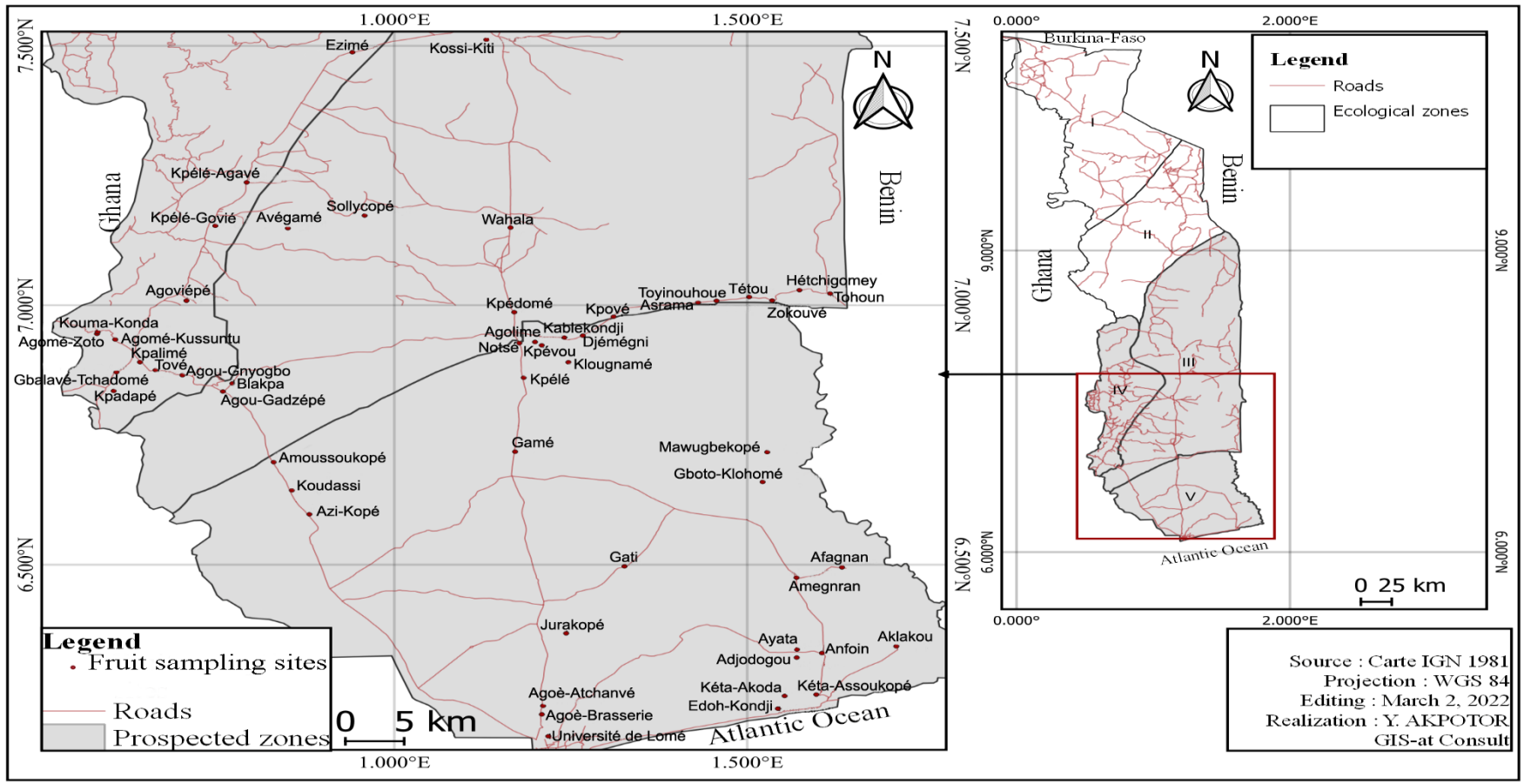


Figure 1: Study zone with the different localities where the fruits sampled came from during the surveys.

Table 1: Number of fruits per plant species sampled in the study zone and number of fruit samples infested by tephritids.

Plant family	Scientific name	Ecological zone	Number of fruits	Fruit weight (kg)	Number of samples	Number of infested samples (%)	Number of fruits per sample
Anacardiaceae	*Mangifera indica* L.	III, IV, V	401	282.2	31	22 (70.97)	4-30
	Spondias mombin Jacq.	III, IV, V	2070	18.2	7	2 (28.57)	54-1015
Annonaceae	*Annona muricata* L.	IV	24	9.7	4	0 (0)	4-9
	Annona senegalensis Pers.	V	6	0.1	1	0 (0)	6
	Annona squamosa L.	IV	6	0.7	1	0 (0)	6
	Uvaria chamae P. Beauv.	V	1614	12.3	1	1 (100)	1614
Cucurbitaceae	*Citrullus lanatus* (Thunb.) Mansf.	V	3	3.1	1	0 (0)	3
	Citrullus sp.	III	29	0.25	1	1 (100)	29
	Cucumis melo L.	III	19	2.3	1	1 (100)	19
	Cucumis sativus L.	V	39	15.5	2	0 (0)	19-20
	Luffa aegyptiaca Mill.	III, V	44	3.3	4	4 (100)	2-21
	Lagenaria siceraria (Molina) Standl.	III, IV, V	54	6.3	4	3 (75)	6-21
	Lagenaria breviflora (Benth.) Roberty	V	4	0.5	1	11 (100)	1
	Momordica charantia L.	IV, V	209	0.8	5	5 (100)	15-81
Euphorbiaceae	*Jatropha curcas* L.	V	16	0.25	1	0 (0)	16

Irvingiaceae	*Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill.	IV, V	40	6.1	3	3 (100)	12-14
Lamiaceae	*Vitex doniana* Sweet	III, IV	360	2.5	2	0 (0)	168-192
Moraceae	*Artocarpus altilis* (Parkinson) Fosberg	IV	3	3.1	1	0 (0)	3
	Ficus sp.	V	59	1.3	1	0 (0)	59
Passifloraceae	*Passiflora edulis* Sims	IV, V	65	3.9	2	0 (0)	6-59
Piperaceae	*Piper guineense* Schum. & Thonn.	IV	1711	0.3	1	0 (0)	1711
Rubiaceae	*Sarcocephalus latifolius* (Sm.) E.A.Bruce.	III, IV, V	419	24.31	16	15 (93.75)	1-104
Rutaceae	*Citrus sinensis* (L.) Osbeck	III, IV	36	6.5	2	1 (50)	5-31
	Citrus grandis (L.) Osbeck	IV	14	4.2	1	1 (100)	14
Solanaceae	*Capsicum annuum* L.	IV, V	543	1.05	3	3 (100)	78-289
	Capsicum frutescens L.	III, IV, V	1293	1.45	4	3 (75)	86-721
	Solanum lycopersicum L.	III	37	0.3	1	0 (0)	37
	Solanum melongena L.	V	32	1.3	1	0 (0)	32
Total			**9150**	**411.81**	**103**	**66 (64.08)**	

RESULTS

Relationship between host plants and fruit flies in the study area

Of the 103 fruit samples (corresponding to 9150 incubated fruits) belonging to 28 species of plants from the three ecological zones combined, those which allowed to recover the fruit flies, belonged to 15 species of plants and 7 families. A total of 6858 flies (3560 males and 3298 females) belonging to 4 genera (*Bactrocera*, *Ceratitis*, *Dacus*, *Zeugodacus*) emerged from 66 fruit samples (corresponding to 5408 fruits), or 64.08% of the all samples (Table 1). These flies belonged to 8 species. *B. dorsalis* and *C. cosyra* were the most abundant with respectively 47.51% (3258 individuals) and 46.03% (3157 individuals) of all the flies recovered during incubation (Figure 2). *Zeugodacus cucurbitae* (Coquillett), *Ceratitis capitata* (Wiedemann), *Dacus ciliatus* Loew, *Ceratitis anonae* Graham, *Dacus vertebratus* Bezzi and *Dacus punctatifrons* Karsch represented respectively 3.40% (233 individuals), 1.90% (130 individuals), 0.69% (47 individuals), 0.38% (26 individuals), 0.06% (4 individuals) and 0.04% (3 individuals) (Figure 2). Of the 8 fly species identified in the three ecological zones combined, *B. dorsalis* and *Z. cucurbitae* were the two alien species.

In ecological zone III, 927 fruits (or 10.13%) allowed to recover 623 flies (341 males and 282 females) (Table 2). These flies belonged to 6 species, *C. cosyra*, *B. dorsalis*, *Z. cucurbitae*, *D. ciliatus*, *C. capitata*, *D. vertebratus* and represented respectively 61.32% (382 individuals), 20.87% (130 individuals), 12.20% (76 individuals), 3.69% (23 individuals), 1.28% (8 individuals) and 0.64% (4 individuals) of all individual flies obtained (Table 2). Out of the 8 identified host plants in this zone, *B. dorsalis* was associated with two of them (*M. indica*, *C. sinensis*). The mango infestation rate by *B. dorsalis* was 2.99 flies/kg at Avégamé and 70.83 flies/kg at Sollycopé. *C. cosyra* was only associated with *S. latifolius* at a rate ranging from 4.62 flies/kg (at Blakpa) to 300 flies/kg (at Zokouvé). *Z. cucurbitae* was associated with 2 species of Cucurbitaceae (*C. melo*, *L. aegyptiaca*) with a rate ranging from 0.87 flies/kg (at Tohoun) to 185 flies/kg (at Tétou) (Table 2).

In ecological zone IV, 650 fruits (7.10%) allowed to recover 1162 flies (579 males and 583 females) (Table 3). These flies belonging to the species (5 in total) *B. dorsalis*, *C. cosyra*, *Z. cucurbitae*, *C. capitata*, and *C. anonae* represented respectively 64.11% (745 individuals), 26.76% (311 individuals), 4.56% (53 individuals), 2.41% (28 individuals) and 2.15% (25 individuals) of all emerged flies. Out of the 9 host plants identified in this zone, *B. dorsalis* was associated with 4 (*A. muricata*, *C. grandis*, *I. gabonensis* and *M. indica*). On the mango, the rate of infestation by *B. dorsalis* was 4.69 flies/kg at Agoviépé and 9.79 flies/kg at Kpélé-Govié (Table 3). *C. cosyra* was only associated with *S. latifolius* with a rate ranging from 130 flies/kg (at Tové) to 360 flies/kg (at Agomé-Kussuntu). *Z. cucurbitae* was associated with 2 species of Cucurbitaceae (*M. charantia* and *L. siceraria*) with a rate ranging from 4.17 flies/kg (at Gbalavé-Tchadomé) to 380 flies/kg (at Kpadapé) (Table 3).

In ecological zone V, 41.87% (3831 fruits) of all incubated fruits from the 3 ecological zones combined allowed to identify 11 host plants. A total of 5073 fruit flies (2433 females and 2640 males) belonging to 7 species were recovered. These are *C. cosyra*, *B. dorsalis*, *Z. cucurbitae*, *C. capitata*, *D. ciliatus*, *D. punctatifrons*, *C. anonae* which represented respectively 48.57% (2464 individuals), 46.97% (2383 individuals), 2.05% (104 individuals), 1.85% (94 individuals), 0.47% (24 individuals), 0.06% (3 individuals) and 0.02% (1 individual) of emerged flies (Table 4). Of the 11 identified host plants, *B. dorsalis* was associated with 4 (*M. indica*, *I. gabonensis*, *S. mombin* and *U. chamae*). The infestation rate of these fruits by *B. dorsalis* varied between 1.85 and 415.83 flies/kg (Table 4). On *I. gabonensis*, this rate was 16.67 flies/kg, 64.35 flies/kg and 415.83 flies/kg respectively at Anfoin, Amégnran and Lomé.

Also, the infestation rate was 1.85 flies/kg at Gboto-Klohomé and 38.57 flies/kg at Davié for *S. mombin*, and 16.89 flies/kg for *U. chamae* at Mawugbékopé. On mango, the infestation rate was 1.93 flies/kg, 3.52 flies/kg,

7 flies/kg, 22.50 flies/kg, 27.20 flies/kg and 57.57 flies/kg respectively in Amoussoukopé, Togoville, Ayata, Adjodogou, Badja and Lomé. *C. cosyra* was found on only *S. latifolius* with rates of 30.45 flies/kg, 66.17 flies/kg, 156.30 flies/kg, 177.50 flies/kg, 182 flies/kg, 216.50 flies/kg and 340 flies/kg respectively at Badja, Mawugbékopé, Gamé, Djémégni, Notsé, Agolime and Jurakopé (Table 4). *Z. cucurbitae* was associated with 4 species of Cucurbitaceae (*L. aegyptiaca*, *L. breviflora*, *L. siceraria*, *M. charantia*) with a rate ranging from 2 to 53.33 flies/kg in the localities of provenance (Table 4).

Among the 7 host plants associated with *B. dorsalis*, the mango (*M. indica*) was the most infested cultivated fruit and the African apple (*I. gabonensis*) the most infested wild fruit ($F = 3.077$, $dl = 6$, $p = 0.008$) (Figure 3).

Level of interaction between the host plants and the tephritids

In conditions associeted to the present study, principal component analysis (F1 and F2: 59.312%) showed a strong interaction between the plant, *S. latifolius* and the fly, *C. cosyra*. Therefore, *S. latifolius* was more infested by *C. cosyra* than any other fly species (Figure 4 and Table 5). Similarly, Cucurbitaceae, *L. aegyptiaca* and *M. charantia* were more infested by *Z. cucurbitae*, and *I. gabonensis* by *B. dorsalis* (Figure 4 and Table 5).

Similarity among study zones

The Sorensen index showed that there was a similarity in terms of specific diversity of fruit flies among the three ecological zones surveyed (Table 6).

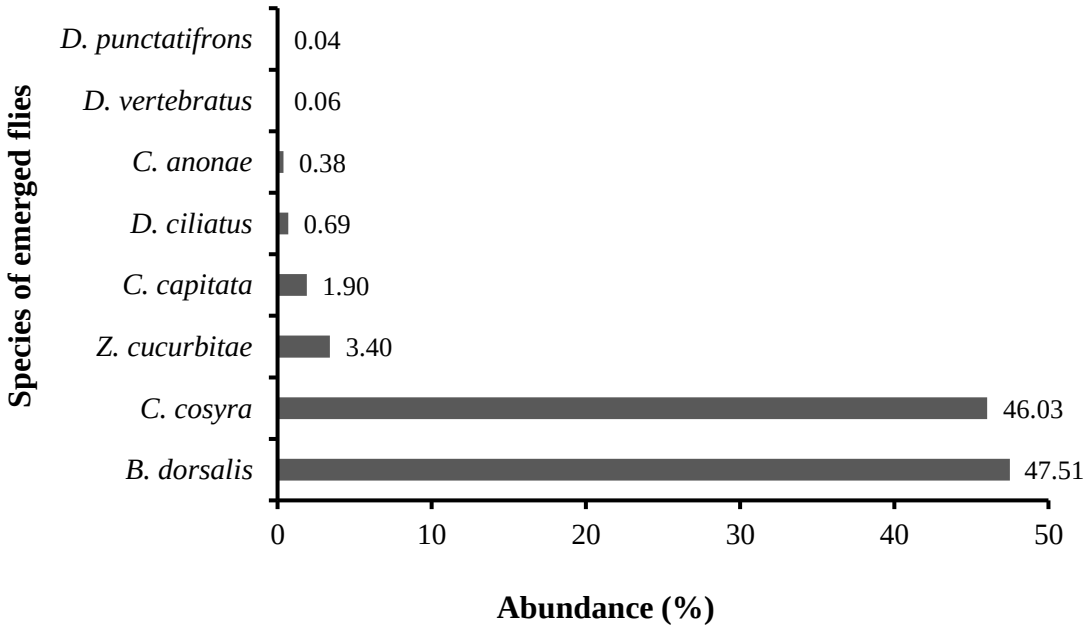


Figure 2: Proportions of fruit fly species emerged from all fruits sampled in ecological zones III, IV and V, and incubated in the laboratory.

Table 2: Relationships between fruit flies, incubated fruits and different localities in ecological zone III.

Locality	Incubated fruit	Number of fruits	Fruit weight (kg)	Emerged fruit fly species	Number of emerged fruit flies			Flies per kg of fruit
					Female (%)	Male	Total number	
Asrama	*S. latifolius*	17	0.70	*C. cosyra*	93 (47.69)	102	195	278.57
Avégamé	*M.indica*	25	14.40	*B. dorsalis*	21 (48.84)	22	43	2.99
Blakpa	*S. latifolius*	18	1.30	*C. cosyra*	2 (33.33)	4	6	4.62
Hetchigomey	*C. sinensis*	31	6	*B. dorsalis*	1 (50)	1	2	0.33
Kpédomé	*S. latifolius*	24	1.20	*C. cosyra*	74 (48.37)	79	153	127.50
Kpové	*C. frutescens*	721	0.30	*C. capitata*	5 (62.50)	3	8	26.67
Sollycopé	*M. indica*	2	1.20	*B. dorsalis*	40 (47.06)	45	85	70.83
Tétou	*L. aegyptiaca*	9	0.40	*Z. cucurbitae*	20 (27.03)	54	74	185
Tohoun	*C. melo*	19	2.30	*D. ciliatus*	11 (52.38	10	21	9.13
				Z. cucurbitae	0 (0)	2	2	0.87
Toyinouhoe	*L. siceraria*	11	0.50	*D. ciliatus*	0 (0)	2	2	4
Wahala	*S. latifolius*	17	0.50	*C. cosyra*	7 (53.85)	6	13	26
Zokouvé	*Citrullus* sp.	29	0.25	*D. vertebratus*	3 (75)	1	4	16
	S. latifolius	4	0.05	*C. cosyra*	5 (33.33)	10	15	300
Total		**927**	**29.10**		**282 (45.26)**	**341**	**623**	

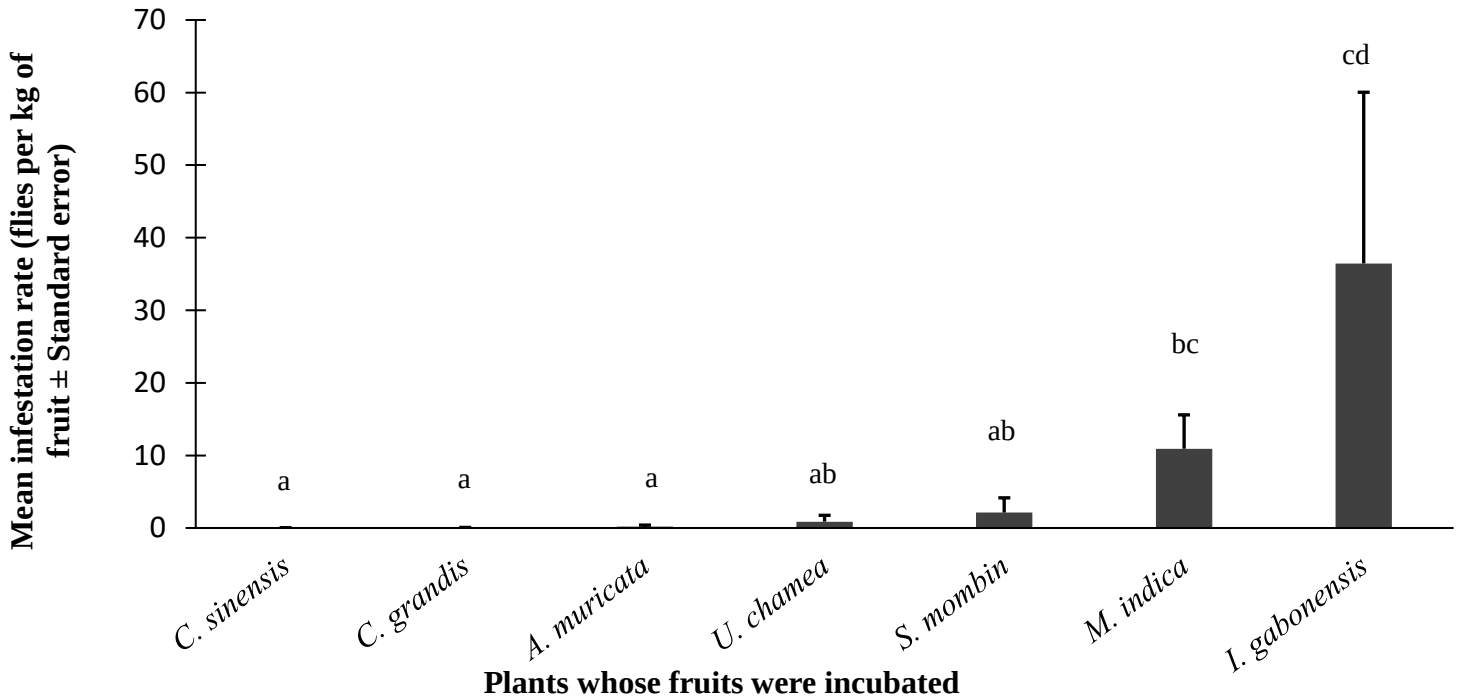
Table 3: Relationships between fruit flies, incubated fruits and different localities in ecological zone IV.

Locality	Incubated fruit	Number of fruits	Fruit weight (kg)	Emerged fruit fly species	Number of emerged fruit flies			Flies per kg of fruit
					Female (%)	Male	Effectif total	
Agomé-Kussuntu	*S. latifolius*	1	0.10	*C. cosyra*	22 (61.11)	14	36	360
Agomé-Zoto	*A. muricata*	9	2.40	*B. dorsalis*	5 (55.56)	4	9	3.75
				C. anonae	16 (66.67)	8	24	10
Agou-Gyogbo	*I. gabonensis*	14	2.30	*B. dorsalis*	231 (51.33)	219	450	195.65
				C. anonae	0 (0.00)	1	1	0.43
Agoviépé	*M. indica*	60	40.50	*B. dorsalis*	88 (46.32)	102	190	4.69
	S. latifolius	31	1.50	*C. cosyra*	96 (43.05)	127	223	148.67
Gbalavé-Tchadomé	*L. siceraria*	6	1.20	*Z. cucurbitae*	3 (60.00)	2	5	4.17
Kpadapé	*C. grandis*	14	4.20	*B. dorsalis*	1 (33.33)	2	3	0.71
	M. charantia	15	0.10	*Z. cucurbitae*	20 (52.63)	18	38	380
Kpélé-Agavé	*C. annuum*	277	0.40	*C. capitata*	2 (40.00)	3	5	12.50
	C. frutescens	176	0.25	*C. capitata*	9 (39.13)	14	23	92
Kpélé-Govié	*M. indica*	10	9.50	*B. dorsalis*	55 (59.14)	38	93	9.79
Lavié	*M. charantia*	31	0.10	*Z. cucurbitae*	7 (70.00)	3	10	100
Tové	*S. latifolius*	6	0.40	*C. cosyra*	28 (53.85)	24	52	130
Total		**650**	**62.95**		**583 (50.17)**	**579**	**1162**	

Table 4: Relationships between fruit flies, incubated fruits and different localities in ecological zone V.

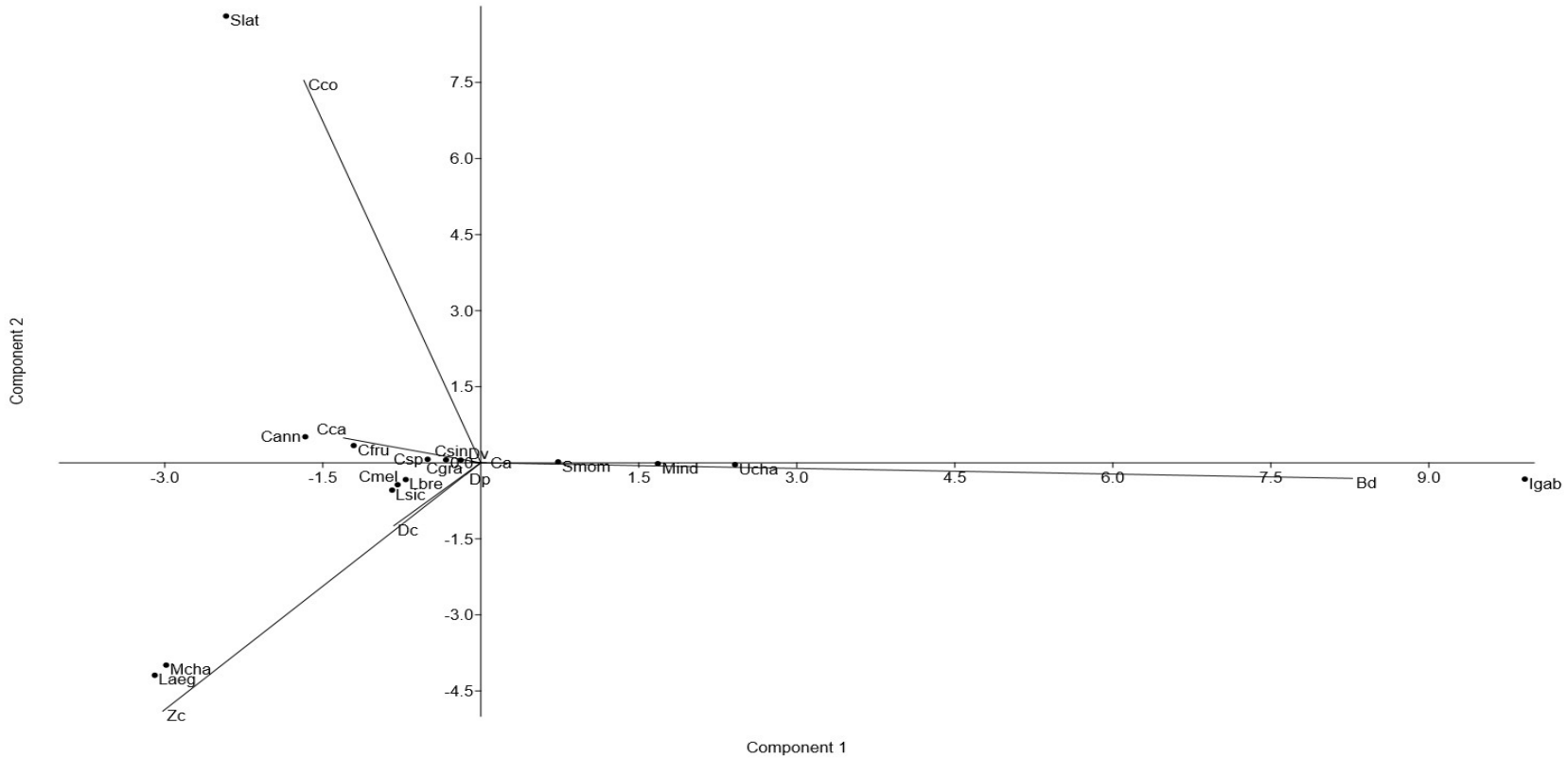
Locality	Incubated fruit	Number of fruits	Fruit weight (kg)	Emerged fruit fly species	Number of emerged fruit flies			Flies per kg of fruit
					Female (%)	Male	Total number	
Adjodogou	*M. indica*	23	13.20	*B. dorsalis*	147 (49.49)	150	297	22.50
Agoè	*M. charantia*	81	0.30	*D. ciliatus*	0 (0)	1	1	3.33
				Z. cucurbitae	8 (22.22)	28	36	120
Agolime	*S. latifolius*	41	2	*C. cosyra*	212 (48.96)	221	433	216.50
Amoussoukopé	*M. indica*	13	8.30	*B. dorsalis*	5 (31.25)	11	16	1.93
Anfoin	*I. gabonensis*	12	1.50	*B. dorsalis*	7 (28)	18	25	16.67
Ayata	*M. indica*	17	11	*B. dorsalis*	43 (55.84)	34	77	7
Aklakou	*L. aegyptiaca*	12	1	*D. ciliatus*	2 (66.67)	1	3	3
				Z. cucurbitae	13 (34.21)	25	38	38
	L. breviflora	4	0.50	*Z. cucurbitae*	0 (0)	1	1	2
Amégnran	*I. gabonensis*	14	2.30	*B. dorsalis*	76 (51.35)	72	148	64.35
Badja	*M. indica*	26	16.80	*B. dorsalis*	235 (51.42)	222	457	27.20
	S. latifolius	35	2.20	*C. cosyra*	34 (50.75)	33	67	30.45
Davié	*S. mombin*	54	0.70	*B. dorsalis*	20 (74.07)	7	27	38.57
Djéménin	*S. latifolius*	27	1.20	*C. cosyra*	118 (55.40)	95	213	177.50
Edoh Kondji	*M. charantia*	26	0.10	*D. ciliatus*	2 (33.33)	4	6	60

Gati	*L. siceraria*	21	2.30	*Z. cucurbitae*	4 (50)	4	8	3.48
Gamé	*S. latifolius*	34	2.70	*C. cosyra*	196 (46.45)	226	422	156.30
Gboto-Klohomé	*S. mombin*	1015	9.20	*B. dorsalis*	11 (64.71)	6	17	1.85
Jurakopé	*M. charantia*	56	0.20	*D. ciliatus*	6 (42.86)	8	14	70
				D. punctatifrons	3 (100)	0	3	15
				Z. cucurbitae	1 (20)	4	5	25
	S. latifolius	1	0.05	*C. cosyra*	5 (29.41)	12	17	340
Kéta-Assokopé	*L. aegyptiaca*	2	0.30	*Z. cucurbitae*	7 (43.75)	9	16	53.33
Klougnamé	*C. annuum*	86	0.25	*C. capitata*	25 (45.45)	30	55	220
	C. frutescens	76	0.30	*C. capitata*	2 (50)	2	4	13.33
Koudassi	*C. annuum*	289	0.50	*C. capitata*	17 (54.84)	14	31	62
Lomé	*I. gabonensis*	18	1.20	*B. dorsalis*	217 (43.49)	282	499	415.83
	M. indica	14	8.20	*B. dorsalis*	233 (49.79	235	468	57.07
Mawugbékopé	*S. latifolius*	104	4.70	*C. cosyra*	154 (49.52)	157	311	66.17
	U. chamae	1614	12.30	*B. dorsalis*	98 (48.04)	106	204	16.59
				C. capitata	1 (25)	3	4	0.33
				C. anonae	1 (100)	0	1	0.08
Notsè	*S. latifolius*	56	5.50	*C. cosyra*	465 (46.45)	536	1001	182
Togoville	*M. indica*	60	42	*B. dorsalis*	65 (43.92)	83	148	3.52
Total		**3831**	**150.80**		**2433 (47.96)**	**2640**	**5073**	



Mean infestation rates of fruits by *B. dorsalis* represented by error bars and bearing the same alphabetical letter are not significantly different (ANOVA followed by LSD test, $P < 0.05$)

Figure 3: Average infestation rate of cultivated and wild fruits associated with *B. dorsalis* in the three ecological zones combined.



Fruit flies : Bd = *B. dorsalis*, Ca = *C. anonae*, Cca = *C. capitata*, Cco = *C. cosyra*, Dc = *D. ciliatus*, Dp = *D. punctatifrons*, Dv = *D. vertebratus*, Zc = *Z. cucurbitae*.
Host plants : Cann = *C. annuum*, Cfru = *C. frutescens*, Cgra = *C. grandis*, Cmel = *C. melo*, Csin = *C. sinensis*, Csp = *Citrullus* sp., Igab = *I. gabonensis*, Laeg = *L. aegyptiaca*, Lbre = *L. breviflora*, Lsic = *L. siceraria*, Mcha = *M. charantia*, Mind = *M. indica*, Slat = *S. latifolius*, Smom = *S. mombin*, Ucha = *U. chamae*.

Figure 4: Principal component analysis carried out taking into account fruit fly species (—) and their hosts (•) identified in the study zone.

Table 5: Eigenvalue and variance of the different factors (components) of PCA.

	Components (F)							
	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**
Eigenvalue	9.873	8.013	7.309	3.882	0.611	0.454	0.012	0.000
Variance (%)	32.739	26.573	24.238	12.874	2.026	1.508	0.041	0.000
Cumulative % (Variance)	32.739	59.312	83.550	96.424	98.450	99.958	99.999	100.000

DISCUSSION

The incubation of the collected fruits allowed to identify 8 species of fruit flies already reported in West Africa in general and in Togo in particular by previous studies (Amevoin et al., 2009; Gomina et al., 2012; De Meyer et al., 2013). *B. dorsalis* was the only economically important fly (Mutamiswa et al., 2021) associeted with citrus (grapefruit and orange) and especially with the mango whose promotion for a few years by the services in charge of the agricultural sector is in progress. Therefore, it was the economically important species associated with the fruits in the study zone. This confirms the work of Gomina et al. (2012, 2020) who showed that *B. dorsalis* was associated with mango, citrus (orange, lemon, grapefruit), avocado, graviola in ecological zones IV and V. However, the mango was also associated with the Tephritidae species of the genus *Ceratitis* such as *Ceratitis silvestrii* Bezzi, *Ceratitis quinaria* (Bezzi), *Ceratitis fasciventris* (Bezzi) and especially *C. cosyra* (Vayssières et al., 2004). Furthermore, the similarity in terms of specific diversity of fruit flies among the three ecological zones surveyed was probably linked to the presence of a large number of host plants for the flies which were common to the three zones. Host availability has been shown to have an impact on seasonal distribution and abundance of fruit flies (Mwatawala et al., 2006). Indeed, during this study, the host plants of the fruit flies (*C. annuum*, *C. frutescens*, *I. gabonensis*, *L. aegyptiaca*, *L. siceraria*, *M. charantia*, *M. indica*, *S. latifolius*) which allowed to recover abundantly and frequently the fruit flies were found in the three ecological zones.

Most of the 15 host plants associated with fruit flies have already been reported in other West African countries (Goergen et al., 2011). During the present study, *Z. cucurbitae* was mainly associated with wild Cucurbitaceae with high infestation rates on *M. charantia* and *L. aegyptiaca*. Indeed, *Z. cucurbitae* is a polyphagous species associated mainly with Cucurbitaceae and secondarily with plant families such as Solanaceae, Passifloraceae, Asclepiadaceae (De Meyer et al., 2014; Ouédraogo et al., 2021). In Burkina Faso, it infests and causes significant damage to economically important vegetables like zucchini (Zida et al., 2020; Ouédraogo et al., 2021).

Among the 7 host plants associated with *B. dorsalis*, the mango (*M. indica*) was the most infested cultivated fruit and the African apple (*I. gabonensis*) the most infested wild fruit. This result was consistent with those of Mwatawala et al. (2006), Vayssières et al. (2014), Hintenou et al. (2016), Zida et al. (2020) who showed that *B. dorsalis* preferentially infested cultivated fruits such as mango, guava, shea and wild fruits like *I. gabonensis*. Furthermore, *B. dorsalis* is a species of great economic importance in West Africa with a proliferation period that coincides with the ripening of mangoes and the rainy season (Mwatawala et al., 2006; Vayssières et al., 2014; Mutamiswa et al., 2021). Thanks to its polyphagy (associated with 80 plant species belonging to 28 families in Africa), this species was able to maintain its populations before and after the mango availability period by developing on wild fruits (substitute hosts) (Goergen et al., 2011; De Meyer et al., 2014). Indeed, during surveys of the present study, *B. dorsalis* was associeted with *I. gabonensis* (African apple) and *U. chamae* sampled towards the end of July which

corresponded to the post-campaign period for mangoes in the study zone during the year (2019) when the incubations were done. Consequently, *I. gabonensis* and *U. chamae* constituted refuge or alternative host plants for *B. dorsalis* in southern Togo.

C. cosyra was associted with *S. latifolius* throughout the study zone with high infestation rates. This confirmed the results of Vayssières et al. (2015), Zida et al. (2020) who showed that *S. latifolius* was a preferred wild host of *C. cosyra*. In addition, this species of fly was native, polyphagous, economically important and very injurious to mangoes (Vayssières et al., 2014). However, under the study conditions, *C. cosyra* was not associeted with the mango probably because of its displacement by *B. dorsalis* on this fruit. Indeed, studies carried out in Kenya showed the existence of interspecific competition between the alien species, *B. dorsalis* and *C. cosyra*. This was materialized by a rapid displacement of *C. cosyra* by the alien species (*B. dorsalis*) a few years after its introduction on the continent (Ekesi et al., 2009). However, in Western Burkina Faso, *B. dorsalis* did not displace *C. cosyra* from mango, but had led to a decrease of their infestation rates (Zida et al., 2020). In any case, in southern Togo, no individual of *C. cosyra* was recovered on the incubated mangoes which were sampled in the three ecological zones, probably to avoid competition with *B. dorsalis*.

Conclusion

At the end of this study, 15 host plants associated with 8 species of fruit flies were identified in ecological zones III, IV and V. Under the present study conditions, ecological zone V was relatively the most diversified in fruit flies and the host plants associated with them. Of the 15 host plants identified, *B. dorsalis* was associated with 7. Regardless of study zone, *M. indica* was the economically important fruit most infested by *B. dorsalis* and *I. gabonensis* was the wild fruit most infested by this species. *C. cosyra* was only associeted with *S. latifolius*, *Z. cucurbitae* with Cucurbitaceae and *C. capitata* with pepper. The results of this study encourage to continue the sampling and incubation of fruits in the south of Togo and to extend this to the center and north to widen the database on the bio-ecology of fruit flies in order to contribute to a long term efficient management of their populations.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

Stydy conception: MG, AT, AKT and IAG; fruit sampling: MG, AT, ANN and AKT; fruit incubation: MG and ANN; morphological identifications: MG; writing-original draft preparation: MG; writing-review and editing: MG, AT, ANN, AKT, IAG and KS; supervision and project administration: KS.

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