Bulletin of Entomological Research

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Research Paper

Cite this article: Zida I, Nacro S, Dabiré R, Moquet L, Delatte H, Somda I (2020). Host range and species diversity of Tephritidae of three plant formations in Western Burkina Faso. *Bulletin of Entomological Research* **110**, 732–742. https://doi.org/10.1017/S0007485320000243

Received: 29 June 2019
Revised: 16 April 2020
Accepted: 27 April 2020
First published online: 2 June 2020

Keywords:
Burkina Faso; fruit flies; host plants; infestation incidence; infestation index; plant formations

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Host range and species diversity of Tephritidae of three plant formations in Western Burkina Faso

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Abstract

In Western Burkina Faso, the host range of fruit flies was evaluated in three plant formations between May 2017 and April 2019. Samples of 61 potential hosts were collected and incubated for fruit fly emergence. Twenty-seven hosts including cultivated and wild fruit were identified. Among cultivated fruit species, mango, and guava were the most infested while high infestation incidences were observed in the fruit of the indigenous plants *Vitellaria paradoxa*, *Annona senegalensis*, *Sarcocephalus latifolius*, and *Saba senegalensis*. Low infestation rates were observed in *Anacardium occidentale*, *Citrus* species, *Opilia celtidifolia*, and *Cissus populnea*. The highest infestation index (1648.57 flies kg^{-1}) was observed from *V. paradoxa*. Eleven new host fruit infested with many fruit fly species are reported in Burkina Faso. A total of 18 fruit fly species were reared; *Bactrocera dorsalis* (42.94%), *Ceratitis cosyra* (29.93%), and *Ceratitis silvestrii* (22.33%) dominated those that emerged. Four fruit fly species have been detected for the first time in Burkina Faso. The main suitable fruit hosts are abundant and available from May through August during the rainy season and become rare and have low infestation from November to April during the dry season. This is the first study of its kind in the region. This study shows that the three plant formations had an impact on population dynamics of the three tephritid species of economic importance in Western Burkina Faso. This information should be integrated into the development of a fruit fly pests management strategy.

Introduction

Fruit flies (Diptera: Tephritidae) are among the most important pests worldwide because of their direct economic impact and the strict quarantine restrictions imposed by many countries to prevent their incursion. Fruit flies constitute a major threat to horticulture in Africa and cause extensive economic losses (Ekesi *et al.*, 2016). Pest fruit flies in Africa were classified into indigenous and invasive species by De Meyer *et al.* (2007), which mainly belong to the genera *Ceratitis*, *Dacus*, *Trirhithrum*, and *Bactrocera*.

In Western Burkina Faso, fruit production is mainly by smallholder farmers and most fruits are supplied to the local urban markets (Zida, 2019). The main fruit exported is mango which is the major fruit product (62.50% of national production) in Burkina Faso (Ouédraogo, 2011). Before the arrival of the oriental fruit fly, *Bactrocera dorsalis* (Hendel), fruit fly damage was mainly caused by the marula fly, *Ceratitis cosyra* (Walker) (Ouédraogo, 2011). Following the detection of *B. dorsalis* in 2005 (Ouédraogo *et al.*, 2010), fruit damage has worsened and can reach worrying proportions. For example, the average rate of damage to the mango varieties Keitt and Brooks has been reported to reach 100% in the middle of the rainy season (Ouédraogo, 2011). Therefore, the implementation of fruit fly management programs with the use of GF-120, male annihilation, and application of various food baits is undertaken in mango orchards to control infestation by fruit flies (Zida, 2019). Unfortunately, despite the control methods deployed, the damage caused by fruit flies on mango remains a concern for small farmers (Zida, 2019). In order to develop an IPM program, data on and a clear understanding of the use of the potential different hosts available in a given area is a necessity (Mwatawala *et al.*, 2009).

In Burkina Faso, previous studies have identified 18 fruit flies in mango orchards by trapping using a wide range of lures (Ouédraogo *et al.*, 2011) and only eight indigenous host fruits (Ouédraogo *et al.*, 2010) in plant formations around mango orchards. However, some earlier rearing studies in other West African countries found 35, >30, 20, and 17 fruit hosts infested with *B. dorsalis*, respectively, in Benin, Senegal, Côte d'Ivoire, and in Togo (N'Dépo *et al.*, 2010; Ndiaye *et al.*, 2012; Gomina, 2015; Vayssières *et al.*, 2015). There is therefore still no comprehensive knowledge of the range of indigenous hosts and infestation indices for any of these species especially in Burkina Faso. According to Mwatawala *et al.* (2009), although mango appears to be a preferred host for several fruit fly species on the continent, several other host fruit also act as refugia, often becoming important sources at the onset of the mango season. There is also a lack of information on relative occurrence of suitable hosts throughout the year and the plant formations in which they are found. The relative abundance and seasonal phenology of fruit flies are highly dependent on the availability of host plants, prevailing weather conditions, and the presence or absence of natural enemies that limit pest population growth (Rwomushana *et al.*, 2008; Mwatawala *et al.*, 2009; Mohamed *et al.*, 2010; Geurts *et al.*, 2012; Badii *et al.*, 2015; Vayssières *et al.*, 2015; Gnanvossou *et al.*, 2017).

In addition to mango orchards, this study takes into account two plant formations most common in Western Burkina Faso; the natural formations that abound with the greatest diversity of indigenous fruit species and the agroforestry parks that mainly comprise shea tree (*Vitellaria paradoxa* C.F. Gaertn.), which is considered the most important woody species in the agroforestry systems (Lamien and Vognan, 1999). According to Geurts *et al.* (2012), the diversity of fruit fly species in a biotope depended on the diversity of the host fruits. Manrakhan *et al.* (2017) stated that plant formations around mango orchards play a major role in fruit fly population dynamics. By taking these three types of plant formations into account, this study provides a better understanding of the role of each plant formation in the emergence and maintenance of fruit fly pests through its floristic composition. Knowledge about fruit fly species and their respective seasons of occurrence in relation to host plant phenology is crucial for understanding fruit fly population dynamics (Aluja and Mangan, 2008). Previous studies showed that fruit fly population dynamics and abundance are mainly influenced by host fruit availability and climatic factors (rainfall, temperature, and relative humidity) (Rwomushana *et al.*, 2008; Mwatawala *et al.*, 2009; Geurts *et al.*, 2014; Mze Hassani *et al.*, 2016; Gnanvossou *et al.*, 2017).

The distribution of fruit fly species is also influenced by competitive interactions between invasive and indigenous species (Aluja and Mangan, 2008). The introduction and successful adaptation of a species out of its natural range of distribution produce drastic changes in the abundance and distribution of competitors (Williamson, 1996; Juliano and Lounibos, 2005). Invasive species can modify native biodiversity, shaping new interspecific interactions either directly or indirectly (Kenis *et al.*, 2009).

This study aims to monitor the seasonality and establish the importance of the different host fruits for fruit fly population development in three types of plant formations in Western Burkina Faso. By doing so, host–fruit fly interactions will also be identified to provide preliminary insight into potential competition for resources between fruit fly species.

Materials and methods

Study sites

The current study was carried out in Western Burkina Faso. A total of six sites in Houet, Kénédougou, and Comoé provinces were chosen for sampling (fig. 1). This area is the major fruit-producing area in Burkina Faso, which borders the republics of Mali and Ivory Coast. In this area, there is an alternation of two distinct seasons: a wet season that extends for 5–6 months (from May to October) and a dry season. It belongs to the South-Sudanian climatic zone and is characterized by an annual average rainfall between 900 and 1200 mm and average monthly temperatures ranging from 25 to 32°C. The vegetation of this area is a wooded savannah with clear forest and patches of dry dense forest and gallery forest (Tankoano *et al.*, 2016). Three types of plant formations including natural fallows, mango orchards, and agroforestry parks were chosen for fruit sampling in each of the six study sites. In each of the six natural fallow sites, three circular plots of 25 m^2 were selected for woody species inventory and fruit sampling during the study.

Sampling effort

Fruits of any plant species in the plant formations were sampled every 2 weeks during their fruit-bearing phase from May 2017 to April 2019. In all plant formations, whenever possible 30 fruits per host species were sampled. Nevertheless, in natural fallows, the number of fruits per sample and the number of samples reared depended mainly on fruit availability and abundance during the season. All samples comprised either tender skinned mature fruits or tender skinned immature fruits (mainly the case for cucurbits and *Saba senegalensis*). Collected fruits were transported to a rearing unit established at Farako-ba Research Station (Bobo-Dioulasso), Institut de l'Environnement et de Recherches Agricoles (INERA).

Laboratory rearing of fruit flies

Each fruit batch was weighed per fruit species, per site, and per date. In each fruit batch, the number of fruit was counted. Fruit samples were then placed in plastic boxes containing sieved and sterilized sand. Larvae leaving the fruit burrowed into and pupated in the sand. Each rearing box was covered with a fine-mesh cloth to prevent dispersing larvae from escaping. Fruit were kept for 6 weeks and the sand was sifted every 5 days to recover tephritid puparia. Large, moist fruit were examined for larvae or puparia before being discarded. Pupae were recovered and counted with soft forceps and placed in Petri dishes (94 mm × 15 mm). Petri dishes containing the pupae were placed in rectangular cages (15 cm × 15 cm × 20 cm) stored in a controlled environment room at 25 ± 1°C and 65 ± 2% relative humidity. Emerged adults were collected when full body coloration was reached and were removed from a rearing cage and kept in pill boxes containing 70% ethanol.

Fruit fly identification

Fruit flies were identified with physical (White, 2006) and electronic (Virgilio *et al.*, 2014) identification keys. Specimens that we could not identify with certainty were sent to the Royal Museum for Central Africa, Tervuren, Belgium for identification. The number of individuals of each fruit fly species was recorded.

Data handling and statistical analysis

Tephritid incidence and infestation rates were determined for all sampled fruit species. Incidence is the number of infested batches (i.e., batches from which fruit flies emerged) in comparison to the total number of batches per fruit species. The infestation rate (used as infestation index) was taken as the number of adult flies per unit weight (1 kg) of fruit. We used generalized linear

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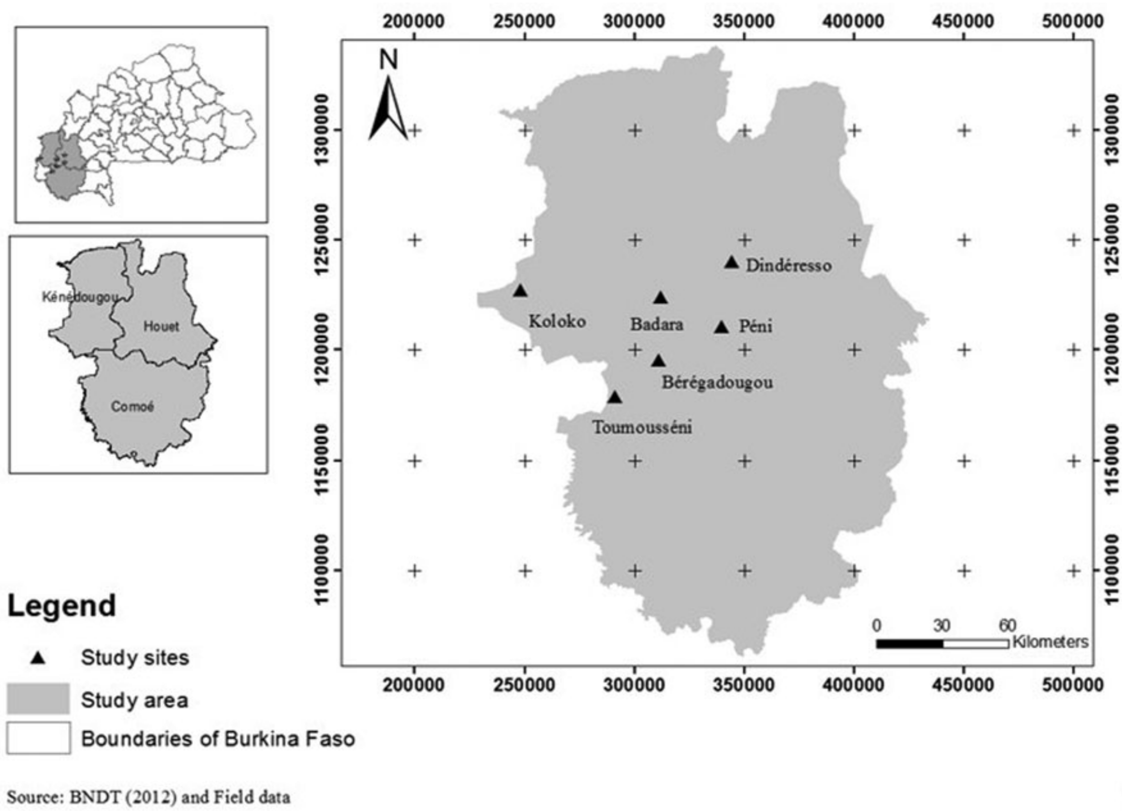

Figure 1. Location of study sites in Western Burkina Faso where infestation of fruit with tephritid fly larvae was determined.

mixed models to test the impacts of the season (wet and dry), plant formations (natural fallows, mango orchards, and agroforestry parks), and their interactions on two response variables: (1) species richness (number of species) and (2) the number of emerged fruit flies (corrected by the number of collected batches). We included the different sites and the year of collections as random factors in models. Due to overdispersion of the data, a negative binomial distribution was used for the two models ('glmer.nb' command, R-package lme4). We used 'plotweb' command in R-package bipartite to illustrate fruit fly–host plant associations.

Results

A total of 945 batches were collected from 61 plant species belonging to 24 plant families for a total of 29,960 fruits, weighing 1903.95 kg.

Host range

Among the 61 fruit species sampled, 27 in 12 families were infested with fruit fly species (table 1). The main plant families infested were Anacardiaceae, Apocynaceae, Cucurbitaceae, Annonaceae, Myrtaceae, and Sapotaceae. Among indigenous fruit species, *V. paradoxa* (shea fruit), *Annona senegalensis*, *S. senegalensis*, *Sarcocephalus latifolius*, and *Sclerocarya birrea* were the main suitable fruit fly hosts while *Mangifera indica* (mango) and *Psidium guajava* (guava) were the most infested cultivated host fruit (fig. 2). According to the fruiting calendar of plants use by fruit flies (fig. 3a), suitable hosts were available throughout the year for fruit fly larval development. However, most suitable host fruit were present during the wet season between May and August. From September, host fruit availability decreased as the March dry season approached. The fruit of various sampled plant species (34/61 fruit species) did not support fruit fly development during this study (table 1). The plant families with more than two uninfested species were Moraceae, Lamiaceae, and Solanaceae. The highest host diversity was found in natural fallows (66%, $n = 18/27$).

Fruit flies

A total of 18 fruit fly species emerged from the 27 host fruit species, comprising ten species of the genus *Ceratitis*, five species of the genus *Dacus*, one species of the genus *Bactrocera* (*B. dorsalis*), one of the genus *Zeugodacus* (melon fly, *Z. cucurbitae* (Coquillett)), and one of the genus *Trirhithrum* (*T. nigerrimum* (Bezzi)) (table 2).

Fruit fly species richness varied between plant formations. In mango orchards, agroforestry parks, and natural fallows, we found seven, seven, and 15 fruit fly species, respectively. However, the type of plant formation and tested interaction had no impact on fruit fly species richness (respectively, $\chi^2_2 = 0.665$, $P = 0.717$ and $\chi^2_2 = 0.407$, $P = 0.816$). In contrast, fruit fly species richness was significantly higher during the wet season than during the dry season ($\chi^2_1 = 14.416$, $P < 0.005$).

Based on the number of fruit fly adults emerged from pupae, three fruit fly species were predominant (fig. 2). In mango orchards, *B. dorsalis* most commonly emerged (62.11% of adult flies) from mango followed by *C. cosyra* (35.57%). In agroforestry

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Table 1. Plant species sampled during the study in Western Burkina Faso to establish tephritid fruit fly infestation

Plant family	Scientific name	Plant formations	Number of batches	Number of fruits collected	Total weight of fruits (kg)	State of fruit flies infestation
Anacardiaceae	*Anacardium occidentale* L.	Mango orchard	10	270	9.22	+
	Lannea acida A. Rich.	Natural fallow	3	300	1.25	–
	Lannea microcarpa Engl. & K.krause	Natural fallow	8	800	3.6	–
	Lannea velutina A. Rich.	Natural fallow	5	500	2.15	–
	Mangifera indica L.	Mango orchard	171	4502	1384.51	+
	Sclerocarya birrea (A.Rich.) Hochst.	Natural fallow	6	300	5.42	+
	Spondias mombin L.*	Natural fallow	8	422	4.46	+
Annonaceae	*Annona senegalensis* Pers.	Natural fallow	39	1056	25.66	+
	Uvaria chamae P.Beauv.*	Natural fallow	10	202	5.32	+
Apocynaceae	*Calotropis procera** (Aiton) R.Br.	Natural fallow	8	196	4.15	+
	*Landolphia dulcis** (Sabine) Pichon	Natural fallow	6	126	3.75	+
	Landolphia heudelotii A. DC.	Natural fallow	18	420	8.35	+
	Thevetia neriifolia Juss. ex Steud	Mango orchard	3	90	2.2	–
	Saba senegalensis (A. DC.) Pichon	Natural fallow	25	344	15.5	+
	Strophanthus sarmentosus DC.	Natural fallow	3	18	2.82	–
	*Tacazzea apiculata** Oliv.	Natural fallow	6	125	8.75	+
Arecaceae	*Borassus akeassii* Bayton, Ouédr. & Guinko	Agroforestry park	3	15	4.8	–
Boraginaceae	*Cordia myxa* L.	Natural fallow	6	600	2.3	–
Chrysobalanaceae	*Maranthes polyandra* (Benth.) Prance	Natural fallow	5	300	3.85	–
	Parinari curatellifolia Planch. ex Benth.	Natural fallow	8	320	4.2	–
Cucurbitaceae	*Citrullus colocynthis** L.	Natural fallow	6	18	10.35	+
	Cucumis sativus L.	Mango orchard	6	63	3.25	+
	Cucurbita pepo L.	Mango orchard	6	40	3.75	+
	*Lagenaria siceraria** (Molina) Standl.	Mango orchard	5	24	9.75	+
Ebenaceae	*Diospyros mespiliformis* Hochst. ex A.DC.	Natural fallow	5	185	2.3	–
Fabaceae	*Detarium microcarpum* Guill. & Perr.	Natural fallow	4	120	1.8	–
Lamiaceae	*Vitex doniana* Sweet	Natural fallow	6	153	1.95	–
	Vitex simplicifolia Oliv.	Natural fallow	3	96	1.25	–
	Gmelina arborea Roxb.	Agroforestry park	3	120	1.6	–
	Tectona grandis L.f.	Agroforestry park	3	130	1.5	–
Loganiaceae	*Strychnos innocua* Delile	Natural fallow	10	123	11.40	+
	Strychnos spinosa Lam.	Natural fallow	8	103	9.65	+
Malvaceae	*Cola cordifolia** (Cav.) R.Br.	Natural fallow	8	145	6.45	+
	Grewia bicolor Juss.	Natural fallow	3	140	0.95	–
	Grewia mollis Juss.	Natural fallow	3	120	0.87	–
Moraceae	*Ficus ingens* (Miq.) Miq.	Natural fallow	6	240	2.76	–
	Ficus ovata Vahl	Natural fallow	3	86	1.35	–

(*Continued*)

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Table 1. (*Continued.*)

Plant family	Scientific name	Plant formations	Number of batches	Number of fruits collected	Total weight of fruits (kg)	State of fruit flies infestation
	Ficus sur Forssk	Natural fallow	6	175	2.65	–
	Ficus sycomorus L.	Natural fallow	7	192	3.82	–
Myrtaceae	*Eugenia nigerina* A.Chev.	Natural fallow	3	300	0.75	–
	Psidium guajava L.	Mango orchard	25	740	32.17	+
	*Syzygium guineense** (Willd.) DC.	Natural fallow	6	182	1.85	+
Opiliaceae	*Opilia celtidifolia** (Guill. & Perr.) Endl. Ex Walp.	Natural fallow	14	860	6.18	+
Phyllanthaceae	*Flueggea virosa* (Roxb. ex Willd.) Voigt	Natural fallow	3	300	0.85	–
Rhamnaceae	*Ziziphus mauritiana* Lam.	Natural fallow	4	313	1.87	–
Rubiaceae	*Crossopteryx febrifuga* (Afzel. ex G.Don) Benth.	Natural fallow	4	400	0.75	–
	Feretia apodanthera Delile	Natural fallow	3	260	1.1	–
	Gardenia erubescens Stapf & Hutch.	Natural fallow	8	178	3.55	–
	Gardenia sokotensis Hutch.	Natural fallow	3	45	0.85	–
	Gardenia ternifolia Schumach. & Thonn.	Natural fallow	3	70	2.1	–
	Sarcocephalus latifolius (Sm.) E.A.Bruce	Natural fallow	59	1953	44.15	+
Rutaceae	*Citrus limon* (L.) Burm.f.	Mango orchard	10	204	9.35	+
	Citrus sinensis (L.) Osbeck	Mango orchard	8	111	7.45	+
Salicaceae	*Flacourtia indica* (Burm.f.) Merr.	Natural fallow	6	244	1.5	–
Sapindaceae	*Blighia sapida* K.D.Koenig	Agroforestry park	4	124	2.54	–
Sapotaceae	*Pachystela pobeguiniana** Pierre ex Lecomte)	Natural fallow	6	422	2.12	+
	Vitellaria paradoxa C.F.Gaertn.	Agroforestry park	305	9493	204.04	+
Solanaceae	*Capsicum frutescens* L.	Agroforestry park	3	100	0.85	–
	Solanum aethiopicum L.	Agroforestry park	3	40	1.25	–
	Solanum lycopersicum L.	Agroforestry park	3	63	1.12	–
Vitaceae	*Cissus populnea* Guill. & Perr.	Natural fallow	10	376	1.87	+

+, infested with fruit flies; –, not infested.
(*) Host fruits detected for the first time in Western Burkina Faso.

parks, *C. silvestrii* represented 55.41% of adults emerged from shea fruits, followed by *B. dorsalis* (40.68%). In natural fallows, *C. cosyra* represented 81.04% of adults emerging from wild host fruit. Among the 46,493 fruit fly individuals recorded from all three plant formations, *B. dorsalis* accounted for 19,965 individuals (42.94%), *C. cosyra* was represented by 13,896 individuals (29.93%), and *C. silvestrii* accounted for 10,367 individuals (22.33%) (fig. 2). We observed a significant effect of season ($\chi^2_1 = 13.920$, $P < 0.005$) and the interaction of season and plant formations ($\chi^2_1 = 66.658$, $P < 0.005$) on the number of adult fruit flies that emerged. More fruit flies emerged from fruit collected during the wet season than the dry season, particularly from mango orchards. The main effect of plant formations had no impact on the number of emerged fruit flies ($\chi^2_2 = 5.490$, $P = 0.064$).

Host–fruit fly interactions

The indigenous fruit fly, *C. cosyra* was found in 13 of the 27 infested fruit species (fig. 2), representing eight plant families. A total of 225 batches were infested with *C. cosyra*. The most infested fruit species were guava (84%, $n = 25$), *S. latifolius* (72.88%, $n = 59$), *A. senegalensis* (74.35%, $n = 39$), *S. senegalensis* (68%, $n = 25$), mango (47.36%, $n = 171$), and *S. birrea* (50%,

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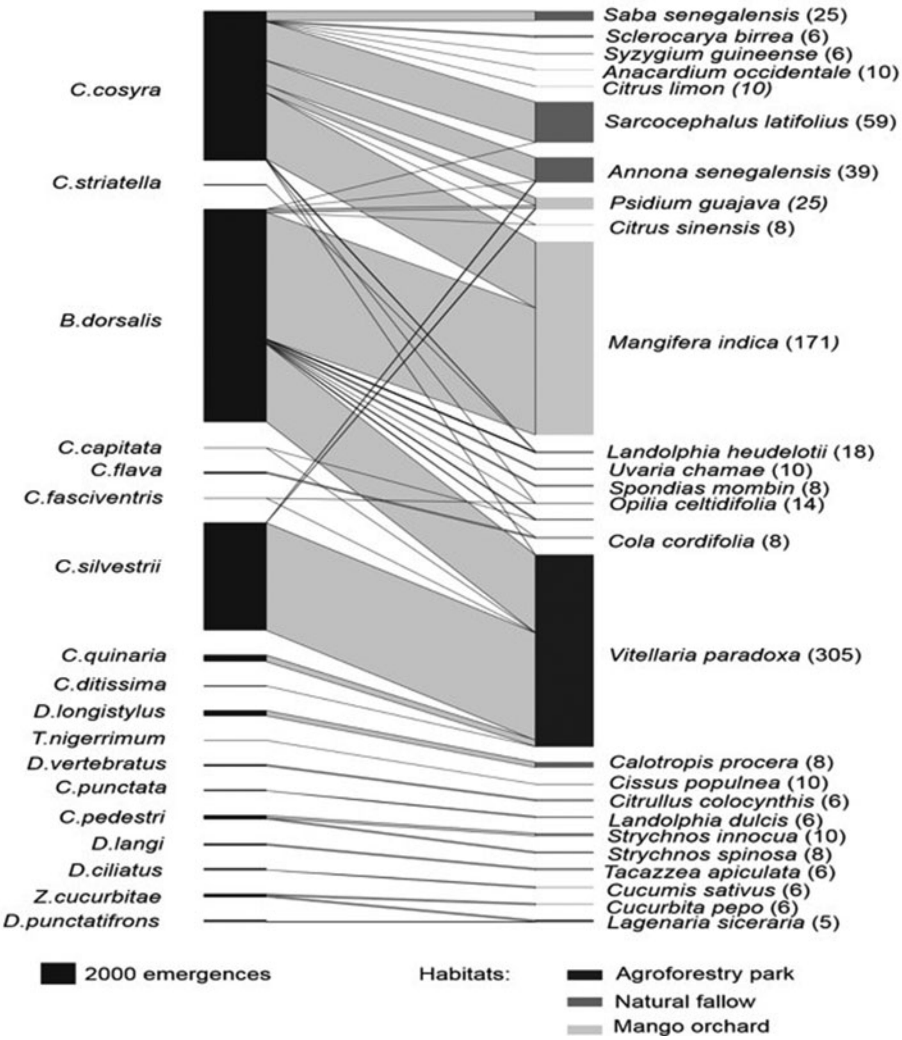

Figure 2. Fruit fly–host network: the diagram shows the interaction between host plant (right) and fruit flies (left). The width of linkages and boxes are proportional to the number of emerged fruit flies. Species have been ranked to minimize overlap linkages as possible.

$n = 6$). The highest number of fruit flies per kg of fruit was from *A. senegalensis* (249.2 flies kg^{-1}). It was followed by mango (220.50 flies kg^{-1}), *S. latifolius* (207.28 flies kg^{-1}), *S. senegalensis* (155.54 flies kg^{-1}), and *S. birrea* (57.92 flies kg^{-1}). According to the fruiting calendar of plant use by *C. cosyra* (fig. 3c), suitable hosts are available throughout the year for this pest species.

Bactrocera dorsalis was reared from 328 batches belonging to 12 fruit species representing nine plant families. Shea fruits (61.31%, $n = 305$), mango (43.85%, $n = 171$), guava (52%, $n = 25$), *Landolphia heudelotii* (66.67%, $n = 18$), *Spondias mombin* (62.50%, $n = 8$), *Uvaria chamae* (50%, $n = 10$), *Pachystela pobeguiniana* (57.14%, $n = 7$), and *Cola cordifolia* (37.5%, $n = 8$) were most infested with *B. dorsalis* (table 2). The highest infestation index for *B. dorsalis* was recorded from shea fruits (821.66 flies kg^{-1}) followed, respectively, by mango (137.50 flies kg^{-1}), *P. pobeguiniana* (79.74 flies kg^{-1}), *U. chamae* (67.66 flies kg^{-1}), *S. mombin* (56.56 flies kg^{-1}), and *C. cordifolia* (47.42 flies kg^{-1}). The fruits from which *B. dorsalis* emerged were often co-infested with *Ceratitis* species including *C. cosyra*, *C. silvestrii*, *C. capitata*, and *C. striatella*. According to the fruiting calendar of plant use by *B. dorsalis* (fig. 3b), no host fruit were available for breeding from February through to April.

A total of 208 fruit batches were infested with *C. silvestrii*, 201 of which were shea fruits. Fruit hosts for breeding *C. silvestrii* were available from April to August. Shea fruits had a high infestation rate for *C. silvestrii* ($n = 1572.90$ adults kg^{-1}).

Discussion

Host range of fruit flies in three plant formations

The number of host plants was higher in the natural fallows (18 host plants) as compared to the mango orchards (eight host plants) and the agroforestry parks (one host plant). These findings could be explained by the composition in plant species of each type of plant formation. Natural fallows mainly comprise several native and wild fruit species. Mango orchards are essentially made up of different mango varieties and sometimes other cultivated host plants (table 1). Shea tree (*V. paradoxa*) was the main fruit species found in the agroforestry parks in addition to vegetable crops grown under the shade of large shea trees (table 1). The seasons had a strong effect on the availability of resources as host fruit for Tephritidae with the highest fruiting period being observed during the rainy season (From May to August) (fig. 3a). A drop in the host fruit availability was observed with the arrival of the dry season (fig. 3a). Mwatawala *et al.* (2006) note that rainfall is considered to be the most important factor for growth and quality of host plants. This seasonality in host fruit

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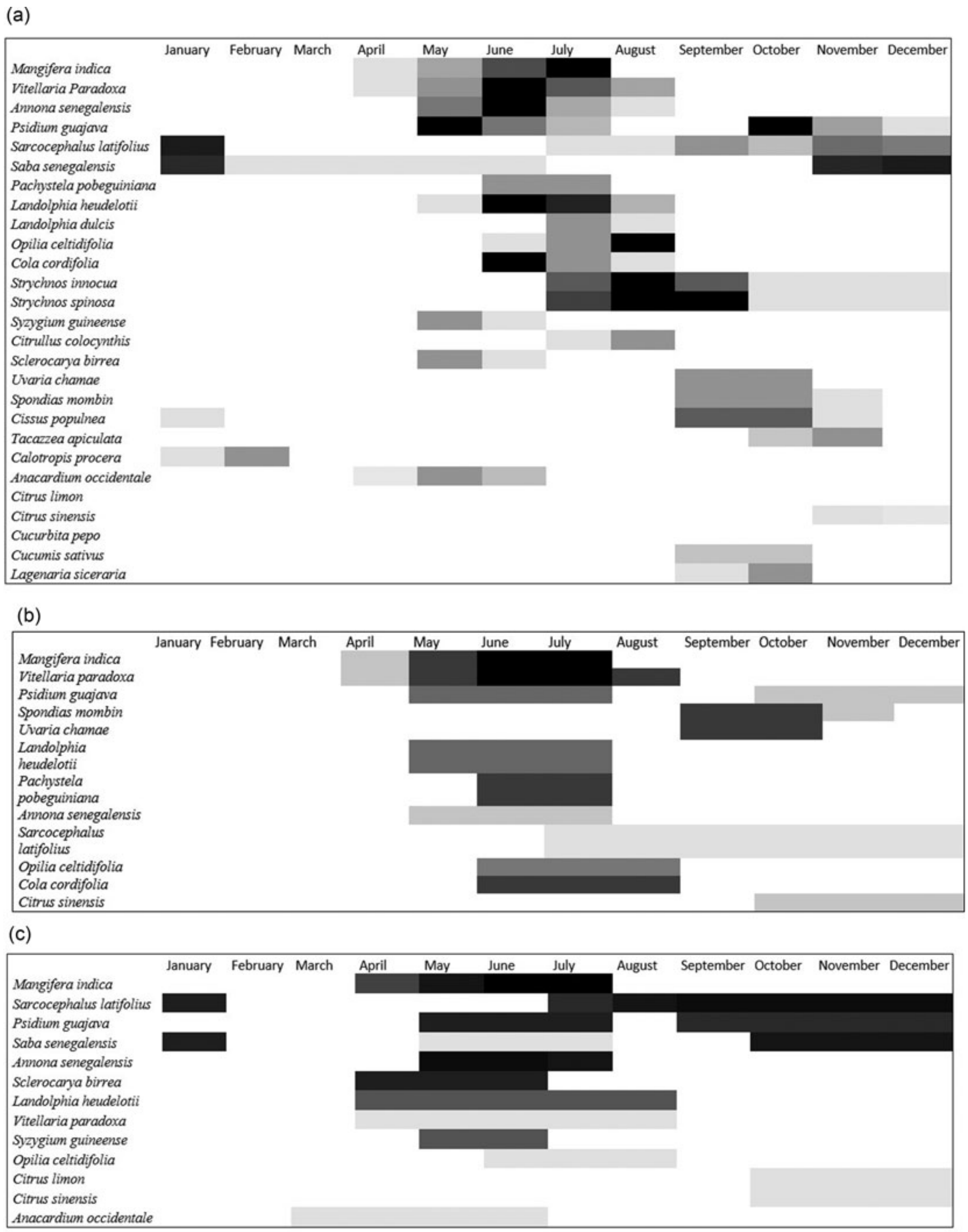

Figure 3. Seasonal availability of host fruit used by tephritid fruit flies in Western Burkina Faso. (a) Fruiting calendar of host fruit used by all fruit flies. (b) Fruiting calendar of host fruit used by *Bactrocera dorsalis* (Hendel). (c) Fruiting calendar of host fruit used by *Ceratitis cosyra* (Walker). The incidence rate of each host fruit was evaluated during its fruiting season. Light gray bars: fruit with low incidence rates; intermediate colors: fruit with intermediate incidence rates; black bars: fruit with high incidence rates. Non-colored space: no suitable host fruit present.

occurrence has a drastic effect on population dynamic of fruit flies (Rwomushana *et al.*, 2008). Eleven fruit species with asterisk in table 1 were identified in this study as fruit fly hosts for the first time in Burkina Faso.

Fruit fly species richness according to plant formations

Fruit fly species richness was higher in natural fallows than in mango orchards and agroforestry parks. Fruit fly species were distributed among the three plant formations but some species including *C. pedestris*, *C. flava*, *C. punctata*, *T. nigerrimum*, *C. striatella*, *D. longistylus*, and *D. langi* were reared exclusively from fruit species sampled in natural fallows. It can be seen that fruit fly species richness was influenced by the host plant diversity in plant formations. Similar results were obtained by Manrakhan *et al.* (2017) who pointed out that the diversity of tephritid species was higher in natural environments than in commercial orchards in South Africa. According to Geurts *et al.* (2012), the diversity of fruit fly species in a biotope depended on the diversity of the host fruit. However, the type of plant

Table 2. Host fruit with which tephritid fruit flies were associated in Western Burkina Faso

Fruit fly species	Fruit host species	Infested/total batches	Infestation index (adults/kg fruit)
Bactrocera dorsalis (Hendel)	*Mangifera indica*	75/171	5.40–137.50
	Vitelleria paradoxa	187/305	15.30–821.66
	Psidium guajava	13/25	9.10
	Spondias mombin	5/8	56.56
	Uvaria chamae	5/10	67.66
	Pachystela pobeguiniana	4/7	79.74
	Cola cordifolia	3/8	47.42
	Landolphia heudelotii	12/18	11.76
	Opilia celtidifolia	7/14	3.36
	Annona senegalensis	2/39	0.27
	Sarcocephalus latifolius	2/59	0.05
	Citrus sinensis	2/8	0.63
Ceratitis cosyra (Walker)	*Mangifera indica*	86/171	2.12–220.50
	Psidium guajava	21/25	49.46
	Sarcocephalus latifolius	43/59	207.28
	Annona senegalensis	29/39	249.2
	Saba senegalensis	17/25	155.54
	Sclerocarya birrea	3/6	57.92
	Landolphia heudelotii	5/18	5.34
	Vitellaria paradoxa	7/ 305	9.30
	Syzygium guineense	3/6	23.68
	Anacardium occidentale	4/10	1.52
	Citrus limon	4/10	3.10
	Citrus sinensis	2/3	0.95
	Opilia celtidifolia	1/14	0.28
Ceratitis silvestrii (Bezzi)	*Vitellaria paradoxa*	201/305	31.45–1572.90
	Psidium guajava	6/25	2.67
	Annona senegalensis	1/39	0.10
	Mangifera indica	5/171	10.56
Ceratitis quinaria (Bezzi)	*Vitellaria paradoxa*	67/305	30.38
	Mangifera indica	2/171	19.40
*Ceratitis pedestris** (Bezzi)	*Strychnos innocua*	4/10	86.54
	Strychnos spinosa	3/8	51.06
Ceratitis ditissima (Munro)	*Vitelleria paradoxa*	4/305	12.12
Ceratitis fasciventris (Bezzi)	*Vitellaria paradoxa*	6/305	11.11
	Mangifera indica	2/171	9.67
	Opilia celtidifolia	1/14	0.56
Ceratitis capitata (Wiedemann)	*Vitellaria paradoxa*	2/305	4.28
	Pachystela pobeguiniana	4/7	33.74
Ceratitis punctata (Wiedemann)	*Landolphia dulcis*	3/6	26.10
*Ceratitis flava** (De Meyer & Freidberg)	*Cola cordifolia*	3/8	24.67
*Ceratitis striatella** (Munro)	*Landolphia heudelotii*	1/18	1.24
Zeugodacus cucurbitae (Coquillett)	*Cucurbita pepo*	3/6	94.69

(*Continued*)

Table 2. (*Continued.*)

Fruit fly species	Fruit host species	Infested/total batches	Infestation index (adults/kg fruit)
	Lagenaria siceraria	3/6	17.25
Dacus ciliatus (Loew)	*Cucumis sativus*	3/6	52
Dacus punctatifrons (Karsch)	*Lagenaria siceraria*	3/5	16.25
Dacus vertebratus (Bezzi)	*Citrullus colocynthis*	3/6	11.02
Dacus longistylus (Wiedemann)	*Calotropis procera*	5/8	213.02
Dacus langi (Curran)	*Tacazzea apicula*	3/6	23.78
*Trirhithrum nigerrimum** (Bezzi)	*Cissus populnea*	4/10	17.40

(*) Fruit fly species detected for the first time in Western Burkina Faso.

formation had no impact on the diversity of fruit flies in the current study. In our study area, many fruit-growing areas are often surrounded by natural vegetation or agroforestry parks where a number of host plants are found. This reason could explain the lack of significant differences between plant formations in fruit fly species richness. In contrast, fruit fly species richness was significantly higher during the wet season than during the dry season. The availability of suitable host fruits during the wet months could explain these findings. Host availability has been shown to have an impact on seasonal abundance of fruit flies in earlier studies (Mwatawala *et al*., 2006; Geurts *et al*., 2014; Vayssières *et al*., 2015). According to Vayssières *et al*. (2008) and Rwomushana *et al*. (2008), the availability and suitability of host plants were found to exert a strong impact on fruit fly population dynamics. Four fruit fly species with asterisk in table 2 were recorded for the first time in our sampling in Burkina Faso.

In order of abundance, *B. dorsalis*, *C. cosyra*, and *C. silvestrii* were the species that emerged from most of the cultivated and wild host plants. These three tephritid species caused important damage on two fruit species of major economic importance in Western Burkina Faso: mango and shea fruits.

The main suitable host fruits for *B. dorsalis* were shea fruits in the agroforestry parks and mango in mango orchards which were available from May to early August. The availability of mango fruits is the most important factor governing population increase in this species (Mwatawala *et al*., 2006, 2009; Rwomushana *et al*., 2008; Fadlelmula and Ali, 2014; Bota *et al*., 2018). In Northern Ghana, Badii *et al*. (2014) argued that among indigenous host fruits, shea fruits recorded the highest infestation index of *B. dorsalis*. In Northern Benin, Shea fruits are considered to be the primary host for *B. dorsalis* (Vayssières *et al*., 2008), confirming our findings. After mango and shea fruit fruiting seasons, it moved on the fruit of *S. mombin* and *U. chamae* in natural fallows from September to early November. These two fruit species could be considered as its alternative host fruits. In Eastern Africa, Tropical almond (*Terminalia catappa* L.) might act as an important reservoir host for *B. dorsalis* (Rwomushana *et al*., 2008; Mwatawala *et al*., 2009). The three plant formations have therefore an impact on seasonal abundance of *B. dorsalis* and its population dynamic.

Suitable hosts for *C. cosyra* were found in mango orchards (mango and guava) and natural fallows during the early rainy season. The abundance of this species coincides generally with the early-mango season in several African countries (Mwatawala *et al*., 2006, 2009; Ouédraogo *et al*., 2011; Badii *et al*., 2015; Vayssières *et al*., 2015). During the dry season, its suitable host fruit were found only in natural fallows including *S. latifolius* and immature fruits of *S. senegalensis*, with their fruiting season extending from September through January. In South Africa and Swaziland, *C. cosyra* distribution generally follows a similar pattern to the distribution of marula tree (*S. birrea*) (De Villiers *et al*., 2013; Magagula and Ntonifor, 2014). In Tanzania, soursop (*Annona muricata* L.) acts as an important host for *C. cosyra* after the mango season (Mwatawala *et al*., 2009; Geurts *et al*., 2012). This tephritid species of sub-Saharan African origin is well adapted to the climatic conditions and indigenous fruit species (Mwatawala *et al*., 2009; Geurts *et al*., 2012, 2014). In agroforestry parks, this species presented a very low incidence rate on shea fruits.

Ceratitis silvestrii, usually considered an oligophagous species, was reared from four fruit species belonging to four plant families. In mango orchards, it attacked mango and the fruit of *P. guajava* while the fruit from *A. senegalensis* were infested in natural fallows. In all cases mentioned above, the incidence rates were very low. These findings are in agreement with those of Vayssières *et al*. (2008) in Northern Benin. Shea fruits in agroforestry parks remained its main host fruit with a higher incidence rate. The highest infestation index recorded for *C. silvestrii* on that fruit was twice the amount found for *B. dorsalis* ($n = 1572.90$ flies kg^{-1} and $n = 821.66$ flies Kg^{-1}, respectively). This is the first study which highlights the economic importance of *C. silvestrii* on shea fruits in West Africa.

Interspecific competition between fruit fly species

Our findings revealed that many fruit fly species shared the same host fruit. The species that were most abundantly reared and that were possible competitors included *B. dorsalis* and *C. cosyra* on mango, and *B. dorsalis* and *C. silvestrii* on shea fruits.

Bactrocera dorsalis (62.11%) and *C. cosyra* (35.57%) accounted for about 98% of adult flies reared from mangoes. It can be seen that 15 years after its first detection in Western Burkina Faso, *B. dorsalis* did not displace *C. cosyra* on mango fruit. In our sampling area, the fruiting period of early-mango varieties corresponds with the period when mature fruit of *A. senegalensis* and *S. birrea* are present in natural fallows. *Ceratitis cosyra* could move from mango to infest these indigenous hosts and thus avoiding strong competition. Mwatawala *et al*. (2009) in Tanzania also found that *C. cosyra* move from mango to soursop (*A. muricata* L.) to avoid interspecific competition.

On shea fruits, *B. dorsalis* (40.68%) and *C. silvestrii* (55.41%) represented more than 95% of adult fruit flies that emerged.

https://doi.org/10.1017/S0007485320000243 Published online by Cambridge University Press

This could be caused by the fact that mangoes and shea fruits are available in the same period in our study area. Mango fruit being the preferred host of *B. dorsalis*, this could give an advantage to *C. silvestrii* in using shea fruit.

Our results showed that *B. dorsalis* did not displace the indigenous species *C. cosyra* and *C. silvestrii* from mango and shea fruits, respectively, in Western Burkina Faso, but had led to a decrease of their infestation rates. This had also been concluded by Zida *et al.* (2020). The results of this study therefore corroborate previous studies showing that, where exotic tephritid species have been introduced into areas already occupied by a native tephritid species, interspecific competition occurs and result in a decrease in numbers and niche shifts of the indigenous species, albeit without leading to complete exclusion (Duyck *et al.*, 2004; Ekesi *et al.*, 2009; Mwatawala *et al.*, 2009). Our results did not concur with those of Ekesi *et al.* (2009) who indicated the rapid displacement of *C. cosyra* by *B. dorsalis* at Nguruman, Kenya, 4 years after its detection in the African continent. Despite its high polyphagy, this major invasive fruit fly did not displace any other indigenous *Ceratitis* spp. on indigenous fruit species or on major cultivated crops, but it increased the overall pest pressure on them in Western Burkina Faso.

Conclusion

This study identified 27 fruit species infested with 18 fruit fly species in three plant formations in Western Burkina Faso. Suitable hosts are mainly available from May to August during the hot and rainy season. The invasive and polyphagous fruit fly species, *B. dorsalis* was the predominant fruit fly species emerged from host fruits followed, respectively, by *C. cosyra* and *C. silvestrii*. Our findings suggest probable interspecific competition between *B. dorsalis* and *C. cosyra* on mango, and between *B. dorsalis* and *C. silvestrii* on shea fruits. Native species of the genus *Ceratitis* dominated the invasive species *B. dorsalis* on indigenous fruit species during our samplings. This study highlighted the importance of the three types of plant formations on seasonal abundance of the main fruit fly species of economic importance in Burkina Faso.

Aknowledgment. We are grateful to Adama Sow, Marcel Soubeiga, Boukary Ouedraogo (Institut de l'Environnement et de Recherches Agricoles) for their assistance in field data collection. Many thanks to Dr Marc De Meyer (Royal Museum of Central Africa) for identifying and confirming some fruit fly species identity. This work was financially supported by Plan Régional de lutte et de contrôle des mouches des fruits en Afrique de l'Ouest (SPLM) and the International Foundation for Science (IFS Grant N° D/5909-1). Special thanks to Dr Dona Dakouo, who initiated this study and who died before it was completed.

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