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Host plants associated with tephritidae in Côte d'Ivoire and discovery of a new fruit fly species: *Dacus longistylus*

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Abstract
Host plants associated with Tephritidae in Côte d'Ivoire and discovery of a new fruit fly species: *Dacus longistylus* Fruit flies are a major entomological problem in Côte d'Ivoire. The fruit flies attack wild plants and cultivated plants that are the foci of re-infestations of orchards. The aim of this study is to inventory the host plants and flies associated with them. Various fruit species are collected and incubated in the laboratory. The collected larvae form the fruits are reared and the adult flies emerged are identified. Thirteen species of fruit flies have been identified and associated with twenty-nine fruit species. The fleshy fruits are the most attacked. *Bactrocera dorsalis* is the majority species with an average of 176.87 ± 90.28 individuals, followed by *Ceratitis cosyra* with 50.9 ± 33.76 individuals. The Bactrocera dorsalis is strongly represented in the mango. The species *Dacus longistylus* is identified for the first time in Côte-d'Ivoire and is associated only with Sodom Apple. The rate attack of fruit fluctuates between 10 and 100% and the level of fruit infestation varies from one fruit to another.

Keywords: Fruit flies, attack, host plants, *Dacus longistylus*

1. Introduction
West Africa had enormous potential for export crops. Among these export crops, mango (*Mangifera indica* L.) represented the most exportation (Anonymous, 2007) [1]. According to these authors, mango is at the forefront of fruit production in West Africa. For their nutritional and commercial value, fruits contribute to the improvement of social well-being and the health status of populations (Ouedraogo, 2007) [2]. In addition to these nutritional values, mango products are suppliers of employment and important currencies to the actors (N'Dépo *et al*., 2010) [3]. Unfortunately, these fruits exported are attacked significantly by fruit flies. These dreaded pests attack a wide range of host plants including berries, citrus fruits and wild crops (Mwatawala *et al*., 2006, Ndiaye 2009, N'Dépo *et al*., 2015, Niang 2017) [4, 5, 6, 7]. The direct damage to the fruits is materialized by egg-laying under the skin of the fruit followed by rotting and falling fruits. In mango orchards, the damage has increased with the presence of the orientale fruit fly, *Bactrocera dorsalis* (N'Dépo, 2010) [8]. This specie is one of the most devastating in the world and the most dangerous of the genus *Bactrocera* according to Toshiyaki *et al*. (2016) [9]. Fruit flies are responsible for important damage and many interceptions of infected fruit containers at European ports. In most West African countries, *B. dorsalis* populations are very low to missing in the orchards during the dry season (Vayssières *et al*., 2015) [10]. These populations reach their peak of growth during the mango production period. It is therefore important to research and characterize the non-preferential areas that harbored flies and serve as the primary source of orchard infestation. The objective of this study was to update the list of host plants for fruit flies in Côte d'Ivoire.

2. Material and Methods
2.1 Study site
The study was conducted from 2005 to 2007, from 2008 to 2009 and from May to June 2017 in four different agro-ecological regions of Côte-d'Ivoire (Figure 1).

- The southern region (subequatorial type climate) with the following localities prospected: Abidjan (Marc Delorme station, 5°20 'N - 4°01' W, annual averages of temperature 25.69 ± 3.3°C and 1625 mm of rain), dominant floristic species are the coconut tree with the

presence of some fruit trees, Azaguié (fruit production station, 5°37' N - 4°02' W, annual averages of temperature 27 ± 1.4°C and 1500 mm of rain). Azaguié area has been for decades a fruit production area (banana, pineapple, papaya, mango), citrus (orange, lemon, pomelo, mandarin, tangelo) and vegetables. It had prospered in fruit and citrus production under the control of the Research Institute for Fruits and Citrus (IRFA) current CNRA, with its experimental plots sheltered the importance of fruit species and tropical citrus fruits.

- The central region (transitional climate between the subequatorial climate and the Sudanese climate) these are the localities of Yamoussoukro (6°48' N - 5°17' W, annual averages of temperature 27,14 ± 2,53°C and 1100 mm of rain), Katiola (8°08' N-5°06' W, annual averages of 27.2 ± 3.1°C and 1000 mm of rain). The vegetation is dominated by grassy savanna with the presence of rhun palms commonly named *Borassus flabellifer* and rattan palms. There are also crops trees: mango, cocoa, coffee, cashew and some citrus (Orange, mandarin, grapefruit).
- The northern region (Sudanese type climate), the main export mango production area with the localities of Korhogo (Lataha station, 9°34' N - 5°37' W, annual averages of temperature 24.42 ± 0.5°C and 928.85 mm of rain) and Sinematiali (9°55 'N - 5°22' W, annual averages of temperature 24.42 ± 0.5°C and 928.85 mm of rain). The vegetation is savanna wooded type. There are also varieties of mango trees (*Kent, Amelie, Brooks, Palmer, Smith, Valencia* etc.), citrus trees, papayas, cashew trees, African locust bean, shea and other wild fruit trees.
- The western central region with Daloa (6°55' N - 6°30' W, annual average temperatures between 21°C and 36°C and 1000 to 1500 mm of rain) has the same climate as the center. The vegetation is a dense forest with a regressive evolution. There are cash crops including cocoa, coffee, oil palm, cashew and rubber. During this study, the fruits collection was done lasting the rainy season.

2.2 Material

2.2.1 Vegetal material

Various fruits are collected. The number of trees visited is a function of the diversity, density and the fruits availability during collection (Table 1).

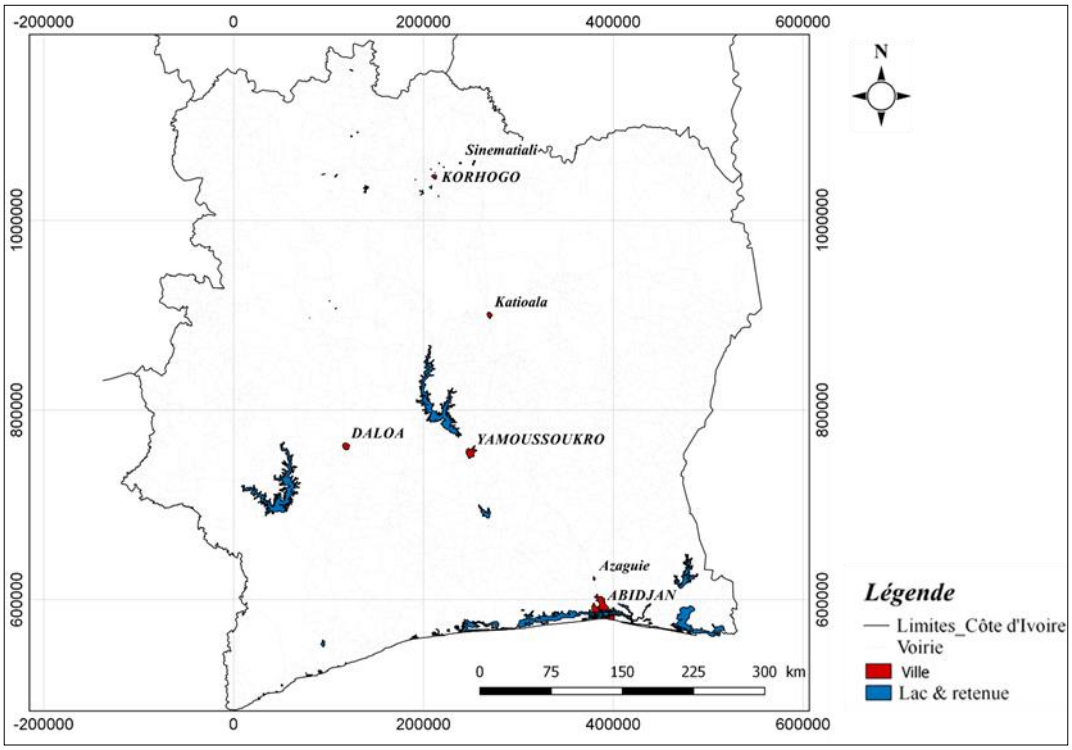


Fig 1: Prospected localities during fruits sampling in Côte d'Ivoire

Table 1: Sampled fruit species and their areas of origin

Localities	Fruit species	Scientific name	Botanical family
Azaguié	Custard apple	*Annona recticulata*	Annonaceae
	Star fruit	*Averrhoa carambola*	Oxalidaceae
	Soursop	*Annona diversifolia*	Annonaceae
	Papaya	*Carica papaya*	Caricaceae
	Tangelo	*Citrus x tangelo*	Rutaceae
	Orange	*Citrus sinensis*	Rutaceae
	Eggfruit	*Pouteria campechiana*	Sapotaceae
	Grapefruit	*Citrus x paradisi*	Rutaceae
	Sapodilla	*Achra sapota*	Sapotaceae
	Bigarad	*Citrus aurantium*	Rutaceae
	Wild mango	*Irvingia gabonensis*	Irvingiaceae
	Combava	*Citus hystrix*	Rutaceae
	Malay apple	*Syzygium malaccense*	Myrtaceae

	Milk fruit	*Chrysophyllum cainito*	Sapotaceae
	Bilimbi	*Averrhoa bilimbi*	Oxalidaceae
	Douka	*Tieghemella africana*	Sapotaceae
	Grapefruit	*Citrus grandis*	Rutaceae
	Jew plum	*Spondias dulcis*	Anacardiaceae
	Rose-apple	*Syzygium jambos*	Myrtaceae
	Mangousteen	*Garcinia mangoustana*	Clusiaceae
	Grenadilla	*Passiflora edulis*	Passifloraceae
	Banana	*Musa sp*	Musaceae
Abidjan	Mango	*Mangifera indica*	Anacardiaceae
	Papaya	*Carica papaya*	Caricaceae
	Avocado	*Persea americana*	Lauraceae
	Cattle stick	*Carpolobia lutae*	polygalaceae
	Melon	*Cucumis melo*	Cucurbitaceae
	Coffee	*Coffeae arabica*	Rubiaceae
Yamoussoukro	Mango	*Mangifera indica*	Anacardiaceae
	Papaya	*Carica papaya*	Caricaceae
	Coffee	*Coffeae arabica*	Rubiaceae
Katiola	Guava	*Psidium goyava*	Myrtaceae
Korhogo	Mango	*Mangifera indica*	Anacardiaceae
	papaya	*Carica papaya*	Caricaceae
	Sodom apple	*Calotropis procera*	Apocynaceae
	Wild custard-apple	*Annona senegalensis*	Annonaceae
	Cucumber	*Cucumis sativus*	Cucurbitaceae
	Pumpkin	*Cucurbita pepo*	Cucurbitaceae
	Cashew nut	*Anacardium occidentale*	Anacardiaceae
	Shea	*Vitellaria paradoxa*	sapotaceae
Daloa	Sodom apple Yellow mombin	*Calotropis procera* *Spondias mombin*	Apocynaceae Anacardiaceae

2.2.2 Incubation and breeding equipment of fruit flies
It consists of plastic basins, sand sterilized by heating in an oven, muslin cloths and breeding boxes.

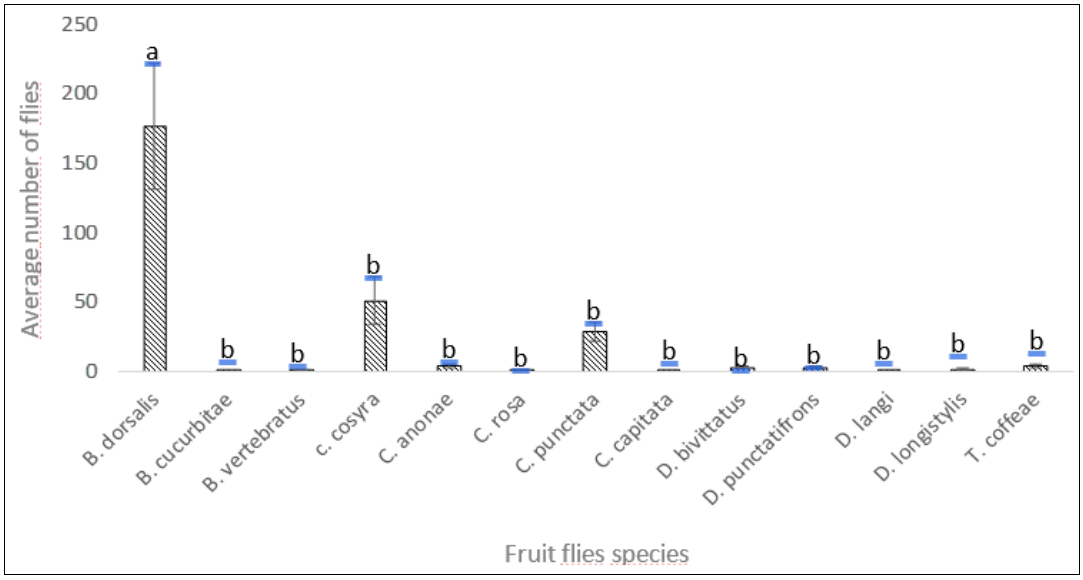
2.2.3 Fly identification equipment
It's a binocular loupe brand "*MOTIC*" with 10 X 20 magnification and fruit fly identification guide (Ekesi and Billah, 2007) [11].

2.3 Methods
2.3.1 Fruit collection, incubation and breeding fruit fly
The ripe fruits were essentially selected, those bearing attack traces and those dragging on the ground. Fruit collection is done every two weeks. The fruits are classified by variety and weighed before incubation. Each variety of fruit is deposited on the sand previously wet in a container. The fruits and the container were closed by a muslin cloth following the same model of N'Dépo *et al*. (2009 and 2010) [12, 3]. On Each container it's noted on the label: variety of fruit, number of fruits, origin, collection date and the fruit weight. The containers are put under a shelter far from the sun's rays. Container supports are brushed with oil to avoid the predators action of ants on the larvae. The rotting fruits are dissected in water and the larvae are recovered by flotation. The pupae and the larvae buried in the container sand are recovered and put in breeding boxes containing sand previously humidified until the emergence of adult flies. The flies are then identified using the binocular loupe and identification guide in the laboratory.

2.3.2 Identification of fruit flies
Fruit flies emerging from different fruits were identified using a binocular loupe brand "*MOTIC*", 10x20 magnification and identification guide (Ekesi and Billah, 2007) [11]. For certain species with identification Uncertain, the samples were shipped at the Royal Museum of Central Africa of Tervuren (RMCA) in Belgium for confirmation.

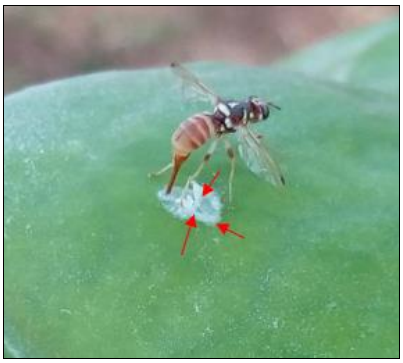
2.3.4 Statistical exploitation of data
The relative abundance of fruit flies, the rate of infestation and attack of the different fruits are subjected to an analysis of variance (ANOVA) at the threshold of 5% using the software *STATISTICA* v.7.1. The averages obtained are classified according to the Student Newmann Keuls test. The host-plant and fruit fly relationship is analyzed by Correspondence Factor Analysis after a transformation of the data with the square root function.

3. Results and Discussion
3.1 Results
3.1.1 Inventory of emerged fruit flies
Thirteen (13) fruit fly species have been identified in the fruits. These include *Zeugodacus cucurbitae*, *Bactrocera dorsalis*, *Ceratitis anonae*, *Ceratis cosyra*, *Ceratitis capitata*, *Ceratitis punctata*, *Ceratitis rosa*, *Dacus bivittatus*, *Dacus punctatifrons*, *Dacus langi*, *Dacus longistylus*, *Dacus vertebratus*, and *Trirhithrium coffeae*. Among these species, *B. dorsalis* is mostly represented with an average of 176.87 ± 90.28 individuals. It's followed by *C. cosyra* with an average of 50.9 ± 33.76 individuals and *C. punctata* with 28.03 ± .13,78 flies. The other species were minority with a relative abundance fluctuating between 0.05 ± 0.03 and 04.35 ± 03.06 flies (Figure 2). Statistical treatments reveal a highly significant difference ($P \leq 0.01$) between species abundance. At the level of the minority species, *D. longistylus* has been identified for the first time in Côte d'Ivoire and found on a single fruit species the Sodom apple (*Calotropis procera*) belonging to the family Apocynaceae (Figure 3).



ANOVA to 5% dl= 12 F= 03.31 P= 0.0001
Averages followed by the same letter are not statistically significant

Fig 2: Average number of flies per species in all fruits from June 2005 to May 2007 and September 2008 to August 2009 and May to June 2017



a

b

a: Egg laying of *Dacus longistylus* on the apple Sodom
b: Larvae of *Dacus longistylus* in the Sodom apple

Fig 3: Damage of *Dacus longistylus* on the Sodom apple

3.1.2 Description of *Dacus longistylus* (Wiedemann, 1830)

D. longistylus has a color ranging from light brown to dark brown through to dark brown for other individuals. The head: has antennas consisting of three segments each and three triangle-shaped ocelli at the top of the head with a pale silvery yellow front. The wings are transparent with a characteristic apical spot at the Sub-costal vein (Figure 4a). There are no spots on the anal stripe of wing. The thorax is devoid of thoracic features. There is a typical triangle-like (dark yellow or pale yellow) spot at the base of the scutum that extends almost one-third of its length (Figure 4b). The scutellum is pale yellow to dark yellow with two yellow marking (katatergite and anatergite) on each side of the thorax. The legs are colored pale yellow with black spots at each femur and terminated with claws (Figure 4c). The abdomen has tergites (segments) colored with brown bands and merged at their ends. In the female, it is terminated by a slender ovipositor and disproportionate hence the name "longistylus" (Figure 4d)

a **b**

c **d**

a: Wing spot ; b : Thoracic spot ; c: Spotted legs ; d : Disproportionate Ovipositor

Fig 4: Few traits of recognition of *Dacus longistylus*

3.1.3 Fruit flies host plants' inventory

A total of 3 436 fruits divided in seventeen (17) families and thirty-five (35) species were collected and incubated. 21 793 fruit flies emerged from twenty-nine (29) fruit species on 35 fruit species collected. They are divided into thirteen (13) species of fruit flies belonging to four genera which are *Ceratitis, Bactrocera, Dacus* and T*rirhithrium* (Table 2). Only Rose-apple (*Syzygium jambos*), Granadilla (*Passiflora edulis*), douka (*Tieghemella africana*), bilimbi (*Averrhoa bilimbi*), Mangosteen (*Garcinia mangoustana*) and Jew plum (*Spondias dulcis*) have not hosted fruit flies. *B. dorsalis* is the majority species (Figure 5) and is strongly represented in mango (83.45%) followed by *C. cosyra* with 15.15%. It has been found in 23 fruit species. The other species, although minor in comparison with the latter, have higher or lower proportions in the fruits collected, including *C. punctata* with 98.45% in the "eggfruit. *D. longistylus* is present only in Sodom apple (*C. procera*) (100%). The infeodation status of fruit flies to certain fruit species has been brought out by factorial correspondence analysis. This analysis shows that *T. coffeae* is associated to coffee, *C. cosyra* is in cattle stick, custard apple and Mango. *C. punctata* is associated to eggfruit, Citrus, Sapodilla and wild custard apple. *D. bivittatus* is present in Papaya and pumpkin and *B. dorsalis* is strongly associated with Mango (Figure 6).

Table 2: Abundance of fruit flies in the various fruits species collected

	Sapodilla (*Achra sapota*)	**(*Anacarduium***	**Soursop (*Annona diversifolia*)**	**Custard apple (*Annona recticulata*)**	**Wild c.apple (*Annona senegalensis*)**	**Cattle stick (*Carpolobia lutea*)**	**Star fruit (*Averrhoa carambola*)**	**Sodom apple (*Calotropis procera*)**	**Papaya (*Carica papaya*)**	**Grapefruit (*Citrus grandis*)**	**Combava (*Citrus hystrix*)**	**Orange (*Citrus sinensis*)**	**Bigarad (*Citrus x aurantium*)**	**Grapefruit (*Citrus x paradisi*)**	**Tangelo (*Citrus x tangelo*)**	**Coffee (*Coffeae arabica*)**	**Melon (*Cucumis melo*)**	**Cucumber (*Cucumis sativus*)**	**Pumpkin (*Cucurbita pepo*)**	**Wild mango(*Irvingia gabonensis*)**	**Mango (*Mangifera indica*)**	**Avocado (*Persea americana*)**	**Gava (*Psidium goyava*)**	**eggfruit (*Pouteria campechiana*)**	**(*Chrysophullum***	**Malay apple (*Syzygium malaccense*)**	**Shea (*Vitellaria paradoxa*)**	**Banana (*Musa* sp)**	**Yellow mombin (*Spondia mombin*)**
Zc	-	-	-	-	-	-	-	-	-	-	-	01	-	-	-	-	-	15	01	-	02	-	-	-	-	-	-		-
Bd	01	05	186	28	-		01		239	67	-	43	108	34	06	-	-	-	07	39	13243	82	02	01	01	10	04	11	01
Cca	-	-	-	-	-	24		-	-	-	-	01	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-
Ca	02	-	246	09	-	-	-	-	-	-	-		04	17	-	-	-	-	-	-	-	-	-	13	-	-	-	-	-
Cc	-	-	-	421	-	680	-	-	-	-	-	-	-		-	-	-	-	-	-	2916	-	-	02	-	-	02	-	-
Cp	54	-	-	-	37	-	-	-	-	-	05	124	439	03	04	-	-	-	-	-	235	-	-	1444	-	-	-	-	-
Cr	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	04	-	-	-	-	-	-	-	-
Db	-	-	-	-	-	-	-		172	-	-	-	-	-	-	-	-	-	41	-	28	-	-	-	-	-	-	01	-
Dl	-	-	03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-
Dlo	-	-	-	-	-	-	-	128	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	227	-	-	-	-	-	-	-	-
Dv	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	-	-	-	-
Tc	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	344	-	-	-	-	-	-	-	-	-	-	-	-	-

NB : - : Absence de mouches des fruits

Zc : *Zeugodacus cucurbitae*, Bd : *Bactrocera dorsalis*, Cca : *Ceratitis capitata*, Ca : *Ceratitis anonae*, Cc : *Ceratitis cosyra*, Cp : *Ceratitis punctata*, Cr : *Ceratitis rosa*, Db : *Dacus bivittatus*, Dl : *Dacus langi*, Dlo : *Dacus longistylus*, Dp : *Dacus puctatifrons*, Dv : *Dacus vertebratus*, Tc: *Trithrum coffeae*

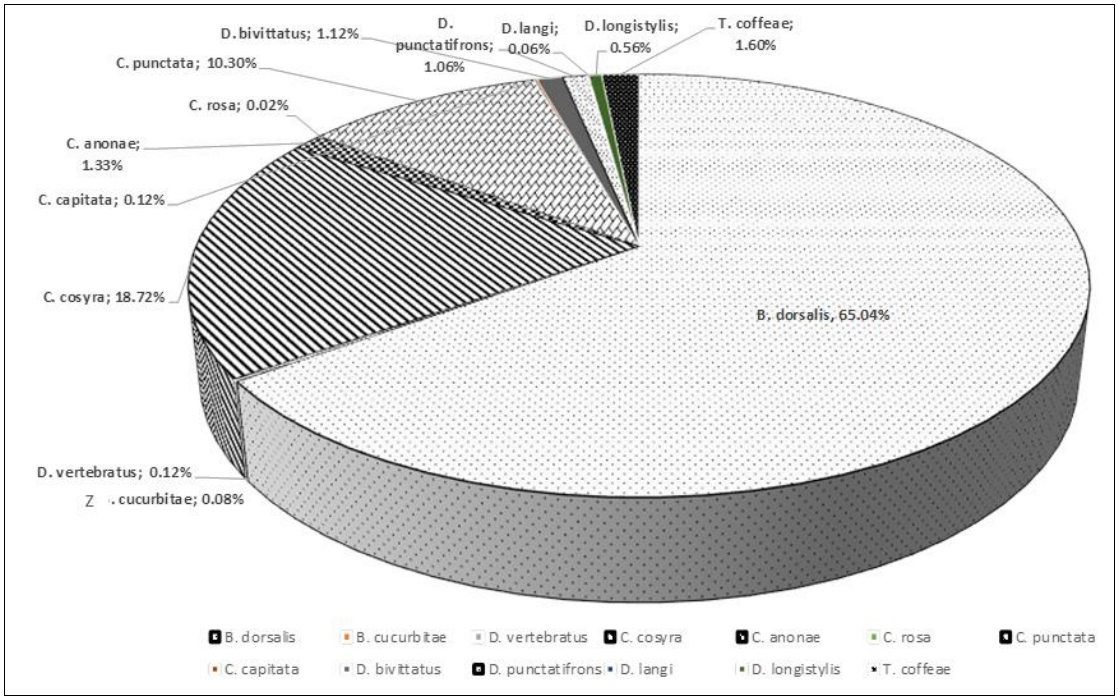
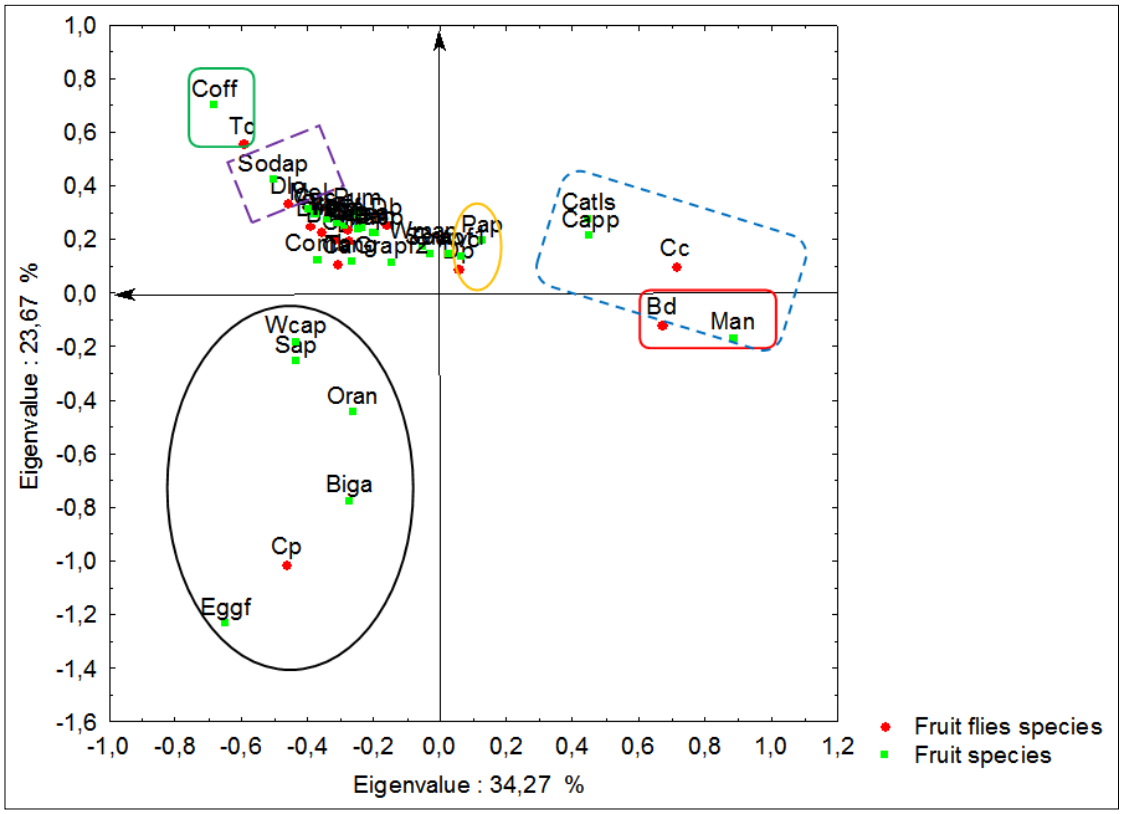


Fig 5: Proportion of flies in fruits

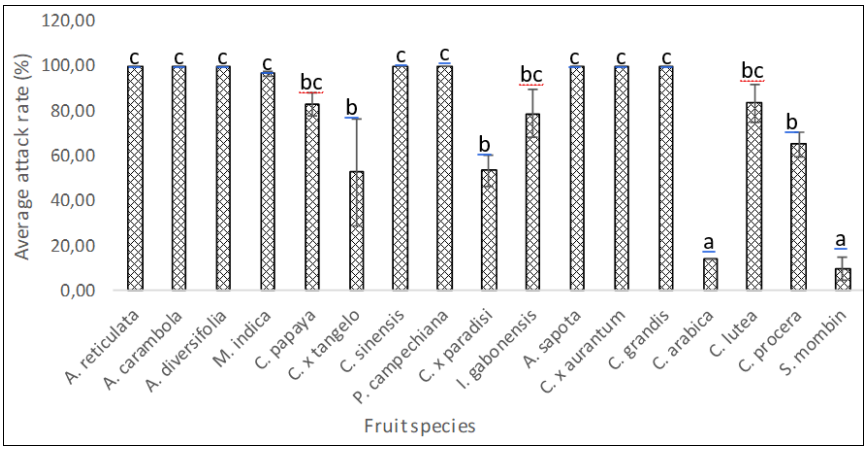


Bi : *Bactrocera invadens*, Zc : *B. cucurbitae*, Ca : *Ceratitis anonae*, Cc : *C. cosyra*, Cca : *C. capitata*, Cp : *C. punctata*, Cr : *C. rosa*, Db : *Dacus bivittatus*, Dl : *D. langi*, Dp : *D. punctatifrons*, Dv : *D. vertebratus*, Dlo : *D. longistylus*, Tc : *Trirhithrum coffeae.*
Sap : *Sapodilla*, Casn : *Cashew nut*, Starf : *Star fruit*, Avo : *Avocado*, Sodap: Sodom apple, Oran: Orange, Wman: Wild mango, Biga: Bigarad, She: Shea, Mel: Melo, Man: Mango, Eggf: Eggfruit, Pap : Papaya, Gav : Gava, Cof : Coffee, Com : Combava, Sour :Soursop, Capp : Custard apple, Wcap : Wild custard apple, Grapf2 : Grapefruit (*C. paradisi*), Tang : Tangelo, Grapf1 : Grapefruit (*C. grandis)*, Cuc : Cucumber, Pum : Pumpkin, Mel : Melo, Ban : Banana sp, Yelm : Yellow mombin, Mapp : Malay apple, Milkf : Milk fruit.

Fig 6: Correspondence of flies to favorite fruit-hosts

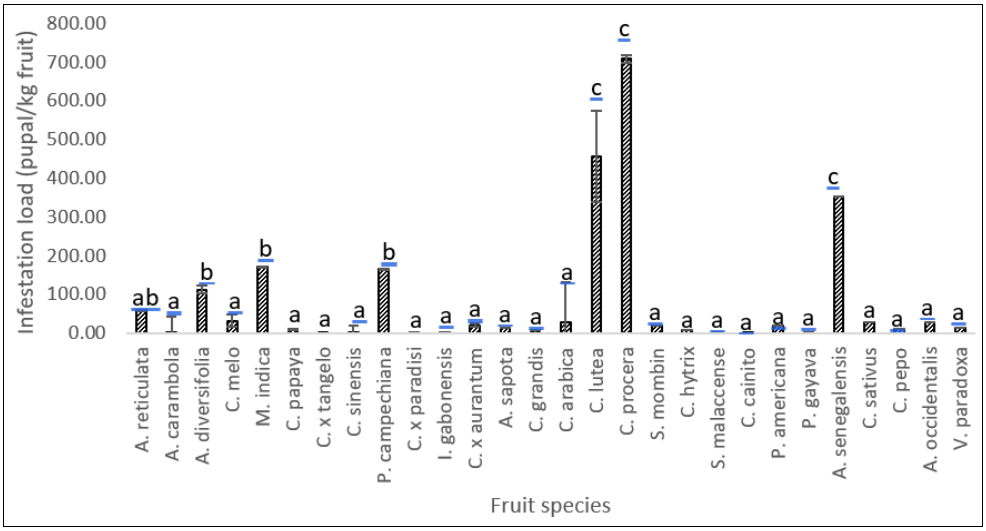
3.1.4 Attack and fruit infestation rate

Fruits bearing fruit flies have a rate of attack and load (infestation) varying from one plant to another depending on their availability and the quantities collected. At the level of attacks, this rate fluctuates between 10 and 100%. Statistical treatments reveal a highly significant difference (P ≤0.01, F= 4.28) between fruit attacks. Except the other fruits, the coffee and yellow mombin have the lowest attack rates 14.28% and 10% respectively (Figure 7). The other fruit species present a strong attack rate varying between 52.67 and 100 % (Figure 7). Two groups are distinguished regarding to the level of infestation or fruit infestation loads. The first have low infestation rate ranging from 0.065 to 32.35 pupae / kg. fruit and the second group of fruit varieties with an infestation rate of more than 50 pupae / kg. fruit. Among these latter, the sodom apple, cattle stick, wild apple, eggfruit and soursop have loads of 708.91 pupae, 456.82 pupae, 352.38 pupae, 165.5 pupae and 112.41 pupae / kg. fruit respectively (Figure 8). Statistical treatments reveal a highly significant difference (P ≤ 0.01, F= 1.91) between fruit infestations.



ANOVA at 5% dl= 16 F= 4.28 P= 0.000
Averages followed by the same letter are not statistically significant

Fig 7: Fruit attack rate



ANOVA at 5% dl= 27 F= 1.91 P= 0.01
Averages followed by the same letter are not statistically significant

Fig 8: Fruit infestation rate

3.2 Discussion

Various fruit fly species have been identified on a wide range of collected fruit-hosts. Most of these fly species except *Dacus longistylus* have already been observed in other parts of Africa (Mwatawala *et al*., 2004, Vayssières *et al*., 2004 and 2005, DAAF, 2013) [13, 14, 15, 16] and also in Côte d'Ivoire (Hala, 2001) [17]. These polyphagous insects attack host fruits with a presence rate depending of plants species. Indeed, the high abundance of *B. dorsalis* in a fruit-host would explain the preferential host status compared to the circumstantial hosts. This is the case of the mango with a strong infestation of *B. dorsalis* and *C. cosyra* because mango orchards, during production, are invaded by a large population of fruit flies so that the fruits are strongly attacked. Also *B. dorsalis* goes an important distance for searching host plants Our results were similar to those of Vayssières *et al*. (2015) [10] in Benin and Keita *et al*. (2016) [18] in Mali, who observed during their work an important population of *B. dorsalis* and *C. cosyra* in mango orchards. *B. dorsalis* was lies found on 23 fruit species in addition to mango. This could be explained by its status as polyphagous insect and super competitor and its great ability to adapt to environmental conditions. Indeed, this important range of host plants would serve as reservoirs and refuges to fruit flies' populations. Our results were similar to the result of Ndiaye (2009) [5]; Ouedraogo *et al*. (2010) [19]; Simde and Dakouo (2017) [20] in Burkina-Faso, where they showed the major role played by alternative host plants in the fruit fly proliferation in non-mango production periods and consequently the re-infestation of mango orchards at the appropriate time. According to Ducky *et al.* (2004) [21] an intense interspecific competition between *B. dorsalis* and other native species would cause displacement of other species to other host plants and ecological niches and consequently increase the number of host fruit species. Also, circumstantial host plants would play a key role in the re-infestation cycle of mango orchards and other orchards. As for the newly identified sodom apple tree as a potential host of Tephritidae, it did not host any other fruit fly species except *D. longistylus*. This may be due to its high toxicity (Maroyi, 2012; Sylvie 2013) [22, 23] which inhibits the development of eggs and larvae of sensitive flies. Indeed, all parts of the plant are toxic, however, the white sap in which the contents are higher, contain a complex mixture of chemical compounds, among which cardiotonic glycosides (cardenolides) some of which are steroidal cardiac poisons (Sylvie, 2013, AISAGARDEN, 2010-2018, Anonymous, 2018a, Anonymous, 2018b) [23, 24, 25, 26]. Thus, Anonymous (2018b) [26] confirms the toxicity of said plant by administering the latex to a mammal. This latex, administered experimentally, was lethal in goats, at the rate of 1 ml / kg per os or 0.005 ml / kg parenterally. The high abundance of *D. longistylus* in the sodom-apple would explain it by an exceptional adaptation and a resistance to the toxicity of this plant.

4. Conclusion

Thirteen fruit fly species have been emerged in the fruits in Côte d'Ivoire. Among them the specie *D. longistylus* has been identified for the first time. Twenty-nine fruit species were identified the fruit flies' host plants in Côte d'Ivoire. The specie *B. dorsalis* is mostly represented in fruits and it's strongly associated with Mango. The attack rate of fruit fluctuates between 10 and 100%. The level of fruit infestation varies from one fruit to another. Fruit flies activity could compromise the agricultural sector in Côte d'Ivoire.

5. References

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