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Host Plants Serving as Refuges for Fruit Fly Populations during Mango Off-Season in Southern Côte d'Ivoire

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Abstract: This study was conducted from October to December 2017 in the CNRA fruit orchards in Azaguié (southern Côte d'Ivoire) in order to identify alternative host plants and refuge areas for mango fruit flies during mango off-season. Six attractants were spread in a 3 to 4 ha orchard, resulting in the capture of 6 440 flies, mainly *Bactrocera dorsalis*. Methyl eugenol and Torula were the most effective attractants, recording 4 380 flies (average: 243.3 flies/trap/week) and 1 484 flies (247.3 flies/trap/week), respectively, of which more than 97% were *B. dorsalis*. Residual fruits from 19 fruit tree species were collected and incubated. Emergence was observed on only four species: *Pouteria campechiana* (Sapotaceae), *Myrianthus arboreus* (Cecropiaceae), *Chrysophyllum cainito* (Sapotaceae), and *Annona esculenta* (Annonaceae). Infestation levels varied: *P. campechiana*: 672 larvae, 545 pupae, pupation rate 85.7%; emerged species: C. punctata (81.5%) and B. dorsalis (18.5%); *Myrianthus arboreus*: 464 larvae, 423 pupae, pupation rate 91.5%; C. anonae domine (94.3%); a native parasitoid, Fopius caudatus, represented 5.7% emergence; *C. cainito*: 33 larvae, 15 pupae, pupation rate 45.5%, emergence 53.3%, exclusively B. dorsalis; *A. esculenta*: 503 larvae, 255 pupae, pupation 71.9%, emergence 48.9%, only B. dorsalis. A total of four fly species were identified (*B. dorsalis, C. cosyra, C. punctata, C. anonae*) as well as a parasitoid, *Fopius caudatus* (Figure 1). The results showed that the orchards of Azaguié constitute an active refuge area for Tephritidae during the inter-seasonal period, promoting the survival of *B. dorsalis* and the presence of secondary host plants, and revealing a potential for natural biological control that remains under-exploited.

Key words: Mangoes fruit flies, refuge areas, host plants, parasitoids, Côte d'Ivoire.

1. Introduction

Mangoes are the 3rd most exported fruit from Côte d'Ivoire. Over 95% of exported volumes are intended for the European market. Export volumes over the last four years have risen from 10 179 tons in 2011 to over 20 475 tons in 2014 [1]. These yields have been achieved following training on quality and the widespread use of approved packaging centers for mango processing.

Current mango production is mainly carried out by small individual producers with cultivated areas ranging from 2 to 3 hectares and production cooperatives in northern Côte d'Ivoire. To this production is added the one generated by industrial plantations ranging from 60 to 350 hectares [2].

The development of the sector makes it possible to curb rural exodus and contributes to the poverty reduction strategy because it generates income for the different stakeholders, from producers to exporters, including packers, sorters, and permanent or seasonal transporters. Despite its economic importance, mango production in Côte d'Ivoire faces numerous health problems including fruit flies, whose nuisance is

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Fig. 1 The parasitoid F. caudatus in a pill box.

exacerbated by the species *Bactrocera dorsalis*.

These health problems lead both to a reduction in the quantity of mangoes exported and to a shortening of the harvest period during the season. Exports are estimated at only 10% of total mango production due to fly bites, with the species encountered being *Bactrocera sp.*, *Ceratitis sp.*, and *Dacus* sp., which reach their peak population during the mango production period. Then, what are their secondary breeding sites during mango off-season? Therefore, this study aims at identifying alternative host plants and areas of fruit fly concentration during mango off-season.

2. Material and Methods

2.1 Study Site

The site was the citrus and fruit orchards of Azaguié, located in the southern part of Côte d'Ivoire. For decades, Azaguié area has been a fruit-producing region (banana, pineapple, papaya, mango, etc.), citrus fruits (orange, lemon, grapefruit, mandarin, tangelo, etc.) and vegetables. Several companies and small farmers have prospered. The activities of Eglin and SCB, banana production companies, are still going on. Azaguié has flourished in fruit and citrus production thanks to the presence on its land of the Research Institute for Fruit and Citrus (IRFA), now CNRA, with its experimental plots that were home to a wide variety of tropical fruit and citrus species. Most of these species are preserved in the CNRA's orchards, but also exist in the plantations of small producers in the area. Recently, parasitoids of fruit flies have been identified in this region [3].

2.2 Fly Trapping

The following traps based on sex attractants (Timaye, methyl eugenol, Decis Trap, Trimedlure) and food bait (Torula) were set:

- Timaye, placed in plastic mineral water bottles painted yellow and pierced with three holes in the lower quarter;
- Methyl eugenol placed in McPhail and Tephri traps with a DDVP (solid insecticide) plate;
- Decis trap placed in Tephri traps;
- Trimedlure placed in McPhail and Tephri traps with a DDVP (solid insecticide) plate;
- Torula placed in Tephri traps.

These attractants were placed randomly in the orchard with a minimum distance of 40 m between two traps. The total area of the orchards was approximately 3 to 4 ha. Among other fruit and citrus trees: see Table 1.

2.3 Collection and Packaging of Captured Flies and Replacement of Attractants and DDVP Plates

The traps were hung on a scaffold branch or support at an average height of 1.4 to 1.8 m above the ground. The traps were placed in an open area that was easily accessible and sheltered from direct sunlight. The branch or trap support was first coated with solid grease so as to prevent ants from preying on the dead Tephritidae adults waiting in the trap.

The traps were checked and emptied every week. The flies were collected and stored in bottles containing 70% alcohol and taken back to the

laboratory for identification and sexing.

On each observation date, samples of pierced fruit were taken back to the laboratory for incubation for 2 weeks. After incubation, they were dissected and washed for larvae counting. The emerged flies were identified.

3. Results

3.1 Trapping of Flies Collected with Attractants

The attractants used made it possible to identify fly species *B. dorsalis*, *C. cosyra*, and *C. punctata* in the fruit orchards of the station of Azaguié. *Bactrocera dorsalis* was the most commonly collected species. However, these results demonstrate the suitability of these attractants in detecting flies. The orchards in which the trapping was carried out were in off-season (no or last fruits on the trees). The average weekly fly collection rates for each of the attractants were well below (Table 1) those obtained in the work of Magloire et al. in 2016 between April and June, the mango season [4]. All these factors contributed to the adoption of these fruit orchards as a refuge area for fruit flies.

3.2 Flies and Parasitoids Identified After Fruit Incubation

Fruit trees at the station of Azaguié cover an area of approximately 19 ha, largely occupied by citrus and mangosteen trees. The trees surveyed above (apart from citrus trees) have been neglected and form islands of fruit tree forests, grouped by species. Most of these trees were not bearing fruit during our survey from October to December, but those identified above were bearing their last fruits (Table 2).

The fruits of nineteen (19) trees were incubated during this period. Flies emerged from four fruits: *Pouteria campechiana* (Sapotaceae), *Myrianthus arboreus* (Cecropiaceae), *Chrysophyllum cainito* (Sapotaceae), and *Anona esculenta* (Annonaceae). The flies gathered during the three surveys showed specificity depending on the fruit. *P. campechiana* was infested by two species, *B. dorsalis* and *C. puntata*, with presence rates of 18.51% and 81.48%, respectively. In Agnan fruit (whose scientific name is yet to be determined), the only fly species to emerge from the pupae was *C. anonae* (94.34%), while in *C. cainito* and *A. esculenta* fruit, only one fly species emerged, *B. dorsalis* (Table 2).

A single species of parasitoid, *Fopius caudatus*, emerged and was identified from a single fruit, *M. arboreus*. On this fruit, *F. caudatus* would parasitize *C. anonae*, the only fly that emerged from this fruit (Table 2).

Table 1 Fly species collected per week in traps equipped with attractants.

Attractants	Number of traps	Trapping period	Total flies captured	Average fly/ trap/ week	Fly species identified	Specific percentage
Methyl Eugenol	3	2016/24/09 to 2016/12/08 (6 weeks)	4380	243.33	*Bactrocera dorsalis*	100%
Trimedlure	2	2016/24/09 to 2016/12/08 (6 weeks)	4	0.33	*Ceratitis cosyra*	100%
Timaye	2	2016/24/09 to 2016/12/08 (6 weeks)	358	29.83	*Bactrocera dorsalis* *Ceratitis puntata*	90% 10%
Decis trap	1	2016/24/09 to 2016/12/08 (6 weeks)	14	2.33	*Bactrocera dorsalis* *Ceratitis puntata*	93% 7%
Torula	1	2016/24/09 to 2016/12/08 (6 weeks)	1484	247.33	*Bactrocera dorsalis* *Ceratitis puntata*	97% 3%
Terpinil acetate	1	2016/24/09 to 2016/12/08 (6 weeks)	200	33.33	*Bactrocera dorsalis*	100%

Table 2 Level of infestation of fruit tree species by fruit fly species in Azaguié, south of the Ivory Coast.

Fruit trees	Fruit		Larvae		Pupae			Flies and parasitoids		
	Number	Average weight	Total number	Number/ fruit	Total number	Pupation rate	Emergence rate	Species	Number	Presence rate (%)
Pouteria campechiana	74	90.75	672	8.65	545	85.68	30.91	*B. dorsalis*	40	18.51
								C. punctata	176	81.48
Myrianthus arboreus	13	442.13	464	68.02	423	91.46	32.56	*C. anonae*	217	94.34
								F. caudatus	13	5.65
Chrysophyllum caïnito	3	300.33	33	11.00	15	45.45	53.33	*B. dorsalis*	7	100
Anona esculenta	41	242.81	503	10.41	255	71.93	48.91	*B. dorsalis*	81	100
Anona montana	3	388.33	18	6.00	11	61.11	0.00	0	0	0
Averrhoa bilimbi	8	26.38	0	0.00	0	0	0	0	0	0
Citrus latifolia	5	127.60	0	0.00	0	0	0	0	0	0
Citrus concoïte	20	18.60	3	0.15	0	0.00	0	0	0	0
Glacenia picata	21	123.33	7	0.33	3	42.86	0.00	0	0	0
Manilkara zapoto	4	168.00	0	0.00	0	0	0	0	0	0
Dacryodes edulis	16	39.38	0	0.00	0	0	0	0	0	0
Averrhoa carambola	26	89.12	9	0.35	8	88.89	0.00	0	0	0
Prunus domestica syriaca	20	9.95	0	0.00	0	0	0	0	0	0
Paciflora eludis	2	78.50	0	0.00	0	0	0	0	0	0
Citrus maxima	10	307.60	0	0.00	0	0	0	0	0	0
Ivingia gabonensis	17	127.47	3	0.18	0	0.00	0	0	0	0
Citrus meyeri	5	127.60	0	0.00	0	0	0	0	0	0
Citrus sinensis	3	133.33	0	0.00	0	0	0	0	0	0
Citrus paradisi shamba	3	257.33	0	0.00	0	0	0	0	0	0
Citrus sinensis	7	175.71	0	0.00	0	0	0	0	0	0

4. Discussion

The results obtained in the Azaguié area confirm that this locality is an important interseasonal reservoir for fruit fly populations in Côte d'Ivoire. The strong dominance of Bactrocera dorsalis in the traps, accounting for up to 97% of captures with torula and all captures with methyl eugenol, illustrates the adaptability and persistence of this invasive species outside mango production period. These observations corroborate the trends described in several West African countries, where B. dorsalis is gradually supplanting native species of the genus Ceratitis thanks to its high ecological plasticity, high fecundity, and wide range of host plants.

The presence of flies in a context of very low fruit availability shows that the CNRA fruit orchards in Azaguié play a major role as a refuge area, allowing adults to survive thanks to alternative resources. The high performance of methyl eugenol and torula attractants, despite residual fruiting conditions, confirms that individual populations remain in the environment and are ready to rapidly colonize mango orchards at season start.

Fruit incubation revealed a set of key alternative hosts among a total of 19 species analyzed. Only four species produced significant emergence: *P. campechiana, M. arboreus, C. caïnito,* and *A. esculenta*. This low diversity of infested fruits probably reflects limited availability of larval resources during the period considered, but also a certain ecological specificity in larvae distribution. For example, C. anonae was almost exclusively associated with *M. arboreus* fruit (94.34%), while *B. dorsalis* completely dominated in *C. caïnito* and *A. esculenta.*

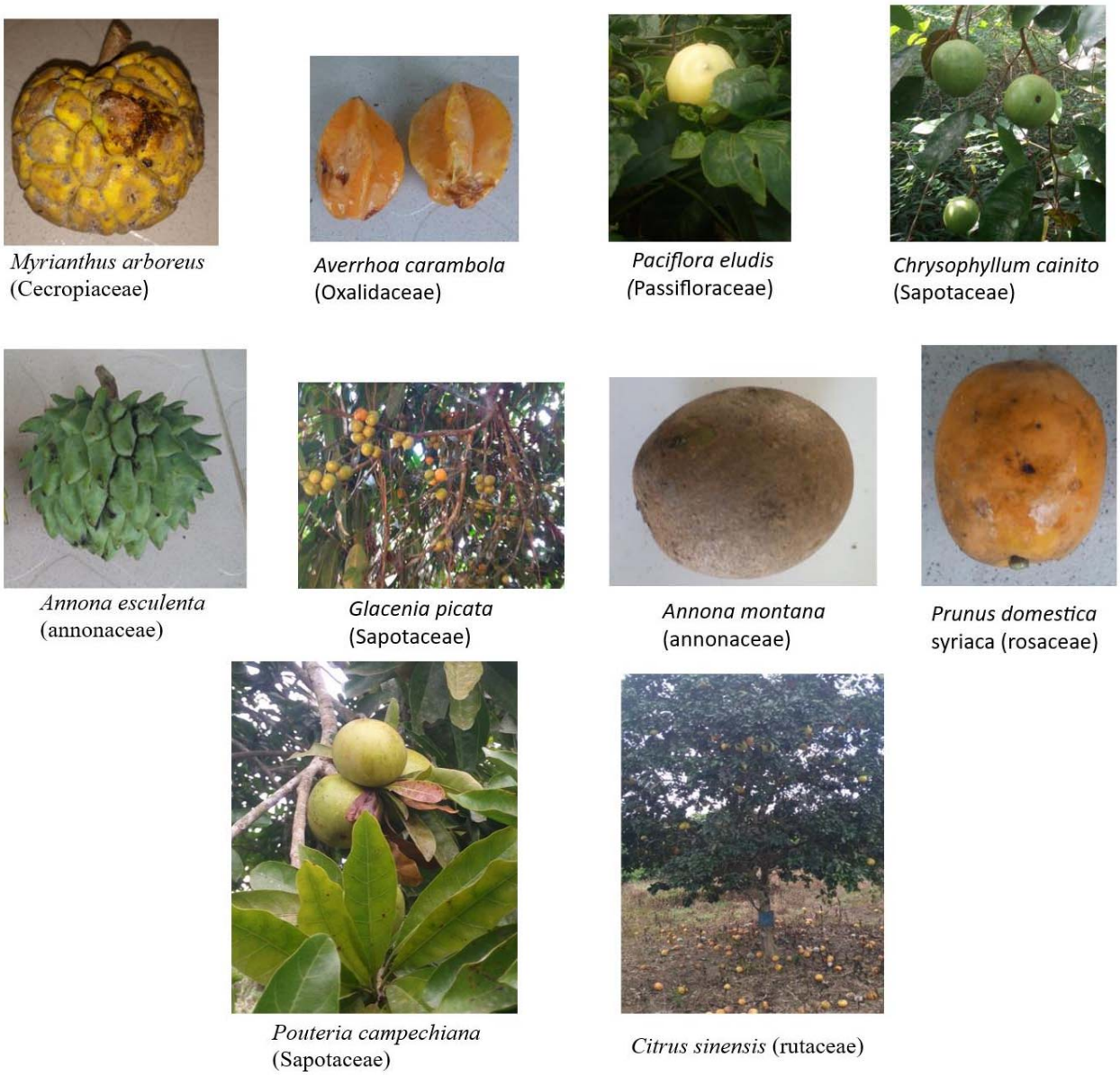

Fig. 2 Some fruit trees used in the experiment.

In *P. campechiana*, the two species *C. punctata* (81.48%) and *B. dorsalis* (18.51%) coexist, suggesting possible interspecific competition within the same fruit. This situation is common in tropical areas where several Tephritidae simultaneously exploit available resources during the transition between production seasons. However, the relatively low emergence of *B. dorsalis* in this fruit, compared to its performance in other species, could be attributed to larval preferences or a lesser ability to exploit certain fruit matrices.

A particularly important finding is the detection of the native parasitoid *Fopius caudatus* in *M. arboreus* fruit at a rate of 5.65%. Although modest, this presence indicates endogenous parasitoid activity in the area, which represents an interesting potential for integrated pest management programs. *F. caudatus* is a larval parasitoid well known for attacking species of the genus Ceratitis, but its observation in a context where *B. dorsalis* is the main invasive species raises the question of its adaptive capacity to new hosts or its retention thanks to native species. However, the low

parasitism rate observed may be the result of high larval density, ecological imbalance caused by the dominance of *B. dorsalis*, or a period of ecological adjustment of the parasitoid.

From an operational standpoint, these results reinforce the idea that residual fruit-bearing areas such as Azaguié must be integrated into national surveillance and control strategies. Their role as refuge areas makes it possible to maintain adult populations capable of massively recolonizing commercial mango orchards as soon as the flowering phase begins. The management of these areas could include:

- sanitation measures (collection and destruction of fallen fruits),
- early placement of attractant traps before mango season,
- and promotion of biological control by strengthening native parasitoid populations.

Finally, continuation of the work is essential so as to cover the entire annual cycle and confirm the trends observed. A more in-depth analysis of host preferences, parasitoid dynamics, and their effectiveness under natural conditions will provide a better understanding of interseasonal survival mechanisms and enable the development of sustainable integrated control strategies adapted to the Ivorian context.

5. Conclusion

With fruit incubation, 4 species of flies have currently been collected and identified: *C. anonae*, *B. dorsalis*, *C. cosyra*, and *C. puntata*. These preliminary results show that this work must continue with the fruiting of all fruit trees at the station and in the surrounding areas in order to confirm that this area is a hotspot for fly species, just like mango-producing areas.

This initial work has also revealed the existence of endogenous parasitoids. A single species, *F. caudatus*, was obtained during the two survey phases carried out on the same fruit, which deserves identification and special attention. Survey must continue until the end of the year in order to discover whether or not other species are present.

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