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Inventory of parasitoids for a biological control of fruits flies (Diptera: Tephritidae) in Côte d'Ivoire

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ABSTRACT:

Flies are major pests of fruits in Côte d'Ivoire. The fight against these pests is achieved by using several methods including parasitoids. The study was carried out under orchards semi naturel conditions in southern, central, northern areas of Côte d'Ivoire. An inventory was made after a mass breeding in box containing fruits placed in sterilized and humidified sand. The fruits were covered by muslin. Four species of fly hosts of the parasitoids were listed: *Bactrocera invadens, Ceratitis quinaria, Ceratitis cosyra* and *Dacus bivittatus*. Eight species of parasitoids belonging to the Hymenoptera order, Braconidae family and three genera were identified: *Diachasmimorpha(D.) tryoni, D. fullawayi, Fopius(F.) arisanus, F. caudatus, F. vandenboschi, F. silvestrii, Psyttalia (P)lounsburyi and P. incisi*. The most abundant species were *D. tryoni, D. fullawayi, F. arisanus* and *F. Caudatus*. Fruits infested by females of *B. invadens* and *C. cosyra* were presented to females of the four parasitoids species. The parasitism rates varied from 26.36 ± 0.31 to 48.95 ± 0.71% on *B. invadens* and 34.33 ± 0.39 to 52.47 ± 0.33 % on *C. cosyra.* The highest parasitism rates were recorded with *D. tryoni* on the two hosts. The species *D. tryoni* seems to be the best parasitoid to control the populations of fruits flies in Côte d'Ivoire.

Keywords:
fruits flies, parasitoids, Tephritidae, biological control.

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INTRODUCTION

Fruits and vegetables are an important source of revenue for exporting countries. The European Union imported nearly 200 000 tons of mangoes, valued at 500 000 euros in 2004-2005 (Fruitrop, 2006). In 2006, the mango field have generated more than 11.2 billion francs CFA to farmers in Côte d'Ivoire. This country is the first producer of mangoes in Africa and the third exporter on the European market (Anonymous, 2007).

Unfortunately, fruits in tropical countries undergoing economic losses due to pest attacks mainly represented by flies (Diptera: Tephritidae). The family of Tephritidae gathers 4500 known species, including 250 pests infesting many fruits such as mango *Mangifera indica* L. (Anacardiaceae), *Citrus* spp. (Rutaceae) and *Psidium guajava* L. (Myrtaceae) (White and Elson-Harris, 1992, Alemany et al., 2006; Da Silva et al., 2006; Llod et al., 2010; Vayssières and al., 2010). In West Africa, flies cause each year, damage estimated at more than 80% of vegetable and fruit crops (Barbet, 2000; Vayssières et al., 2004). In Benin, damage on mango ranged from 17 to 73% in April to mid-June in central and northern areas during seasons 2005-2006 (Vayssières and al., 2009). In Côte d'Ivoire, the losses in the northern area, ranged from 43 to 50% respectively on the mango varieties *Keitt* and *amélie* to reach 80% at the end of the season (Hala, 2001). Flies populations are ongoing throughout the year with seasonal fluctuations, they appear chronologically from the beginning (March) at the end of the fruit season (June-July): *Ceratitis cosyra* (early species), *Ceratitis fasciventris* and *C. quinaria* (species semi late) and *Bactrocera invadens* (species late) (Hala et al. 2008; N'depo et al., 2009; 2010). However, exports require crops of top quality. Moreover the import into countries where climatic conditions allow the establishment of these pests is subject to drastic measures of quarantine. The economic losses are considerable, whether lost profits due to loss of production, loss of markets due to phytosanitary regulations or the cost of crop protection (Rousse, 2007).

The fight against Tephritidae was based primarily on the use of pesticides, alone or mixed with food attractants (Roessler, 1989). But, the massive use of pesticides pollutes the environment and can be harmful to human health. Also, several species of insects have become resistant to chemical pesticides and cause extensive damage to crops (Van Driesche and Bellows, 1996). The problems caused by pesticides led to the development of less pollution methods, as the biological control using parasitoids (Boivin, 1999). The use of parasitoids to control fruits flies was manly studied in the exporting fruit countries. This method gave promising results and is currently used successfully in orchards invaded by fruits flies (Legner, 2006, Rousse, 2007). In Côte d'Ivoire, any study was conducted on the biological control of fruit flies. The objective of this work is to identify different parasitoids of fruits flies, to assess their potentialities in biological control in this country.

MATERIAL AND METHODS

Study areas

The tests were carried out in experimental stations located in three agro-ecological areas.The fruits used came from four hearths of infestation by fruits flies. The choice of experimental stations was related to the presence of orchards in these areas: Southern area (subequatorial climate) with two sites: Marc Delorme experimental station in Abidjan (lat. 5° 20 ' NR, length. 4° 01 ' W; annual averages of 25.69 ± 3.3 °C and 1625 mm of rainfall); Azaguié experimental station (lat. 5° 37 ' NR, length. 4° 02 ' W; annual averages of 27 ± 1.4 ° C and 1500 mm of rainfall). Central area (climate of transition between the subequatorial climate and the Sudanese climate): Lamto experimental station of tropical ecology (lat. 6° 13 'NR, length. 5° 02 ' W; annual averages of 26.7 ± 3.1 °C and 1176 mm of rainfall). Northern area (Sudanese climate): Korhogo, Lataha experimental station of production (lat. 9° 34 ' NR, length. 5° 37 ' W; annual averages of 24.42 ± 0.5 °C and 928.85 mm of rainfall). The study was conducted from February 2009 to July 2010.

Inventory of fruits flies and parasitoids

Several fruits infested by females' fruits flies were collected and laid out by variety and area. These were: fruits of mango tree (*Mangifera indica* L.), papaw tree (*Carica papaya* L.), egg yolk tree (*Richardella campechiana* Pierre), carambola tree (*Averrhoa carambola* L.) and orange tree (*Citrus sinensis* Osbeck). Two kilograms of each fruit (five or six fruits) were placed in box (60 x 45 x 30 cm) containing sterilized sand. The sand was sterilized using an autoclave at 121°C and 1.5 bars of pressure and was slightly humidified. Three boxes were made for each fruit. Boxes were covered with muslin with 0.5 mm mesh. The contour of the boxes was coated with grease to prevent ants' penetration.

Eggs and larvae continued their development in hosts. Then, larvae left fruits and became nymphs in sand. Five days later, deteriorated fruits were dissected and washed, as well as the sand of the box, with water. Larvae and nymphs were recovered by floating and sifting and placed in boxes containing sterilized and humidified sand for emergence. Adult flies and parasitoids were collected after emergence. The insects were identified using guides of identification (De Meyer, 1996, 1998, 2000; Hurtrel, 2000; Wharton, 2006; Rousse, 2007) and binocular magnifying glass. They were then counted. The average number (Na) of each species of fly and parasitoid was calculated.

$$Na = \frac{\Sigma\, xini}{\Sigma\, ni}$$

xi: number of individuals emerged by species; ni: number of boxes

Determination of parasitism rate

The test was conducted at Korhogo Lataha experimental station. Determination required specific breeding of flies and parasitoids. Insects used were these which presented highest numbers: flies *B. invadens* and *C. cosyra*, two larval-pupal parasitoids of *D. tryoni* and *D. fullawayi*, two egg-pupal parasitoids of *F. arisanus* and *F. caudatus*. The insects were fed in water added with honey (50: 50), as of their emergence (Roux et al., 2008). The fruit host was *keitt* variety mango because of its high sensitivity to the flies. The fruits were aged 100 days and almost ripe (N'Guetta and Hala, 1999). They were protected as of their appearance by sleeves in muslin.

Specific breeding of fruits flies

Adults of *B. invadens* and *C. cosyra*, newly emerged were laid out by species, in cages of breeding. For each species of fly, ten couples aged 3 days were placed each one in a sleeve in muslin protecting six healthy fruits on a tree. Every day, infested fruits were withdrawn from sleeves then incubated in boxes containing sterilized and slightly humidified sand. Five days later, incubated fruits were immersed. Pupae were recovered by floating and larvae by sifting. Larvae and pupae were then bred in plexiglass boxes (28 × 27 × 9.5 cm) containing sterilized and slightly humidified sand, until the emergence of adults.

Specific breeding of parasitoids

Infested fruits, withdrawn of sleeves posed on the trees, were placed at laboratory in cages containing each one a couple of sexually mature parasitoids aged 8 to 10 days (Ramadan and al., 1992; Vargas and al, 2002; Rocha and al, 2004). The infested fruits were withdrawn 5 days later then placed in boxes containing sterilized and slightly humidified sand. Two days later, incubated fruits were immersed. Nymphs were recovered by floating and larvae by sifting. Larvae and nymphs were then bred in plexiglass boxes (28 × 27 × 9.5 cm) containing sterilized sand, slightly humidified, until the emergence of flies and parasitoids adults.

Parasitism rates

For this test, four batches of 30 couples of each species of fly host and two batches of 30 couples of each species of parasitoids were made, as of their emergence. One female of fly aged 3 days was introduced into a sleeve in muslin, protecting six fruits on a tree. Two days later, the female of fly was withdrawn from the sleeve then replaced by one female parasitoid of 10 days old and capable of laying. Five days later, fruits were withdrawn for incubation. The experiment was followed until the emergence of the last insect. The average parasitism rate (Pr) was calculated for each species of parasitoid.

$$Pr = \frac{\Sigma\, xini}{\Sigma\, ni} \times 100$$

$$xi = \frac{Npe}{Nt}$$

ni: Number of the females; Npe: Number of emerged parasitoids adults; Nt: Total number of emerged insects (flies and parasitoids).

Statistical analysis

Data processing was performed using Statistica software version 6.0. An analysis of variance (ANOVA) revealed significant differences between the data. The test of Student-Newman-Keuls at 5% was used to classify the means into homogeneous groups.

RESU LTS

Inventory of fruits flies and parasitoids

Abundance and distribution of fruits flies

Southern area

In Abidjan, species met were *Bactrocera invadens* Drew Tsuruta & White and *Ceratitis cosyra* Walker. *B. invadens* was always majority with a proportion of 87.56 ± 1.07% on the mango cameronian variety and 87.07 ± 1.28% on the mango polyembryonic variety. *C. cosyra* was lowly represented in this area with a proportion of 12.44 ± 1.07% on the mango cameronian variety and 12.92 ±1.28% on the mango polyembryonic variety. Statistical analysis showed highly significant differences between percentages of flies ($F = 4406.18$; $df = 3$; $p < 0.001$) (Figure 1).

In Azaguié, two species of fruits flies were identified: *B. invadens* and *Ceratitis quinaria* Bezzi. These two species of flies emerged from all the incubated fruits (papaw, "egg yolk'' carambola, orange). The species *B. invadens* was dominant in papaw and orange with respective proportions of 79.43 ± 0.19% and 89.69 ± 0.27%, while the species *C. quinaria* was more abundant in egg yolk (78.69 ± 0.31 %) and carambola (80.45± 0.12%). Statistical analysis indicated highly significant differences between percentages of flies ($F = 3870.32$; $df = 7$; $p < 0.001$) (**Figure 1**).

Central area

In Lamto, three species of fruits flies were listed: *B. invadens*, *C. cosyra* and *Dacus bivittatus* Bigot. *B. invadens* was majority in papaw (72.68 ± 0.18%) and the two varieties of mangoes: polyembryonic (85.32 ± 0.59%), cameronian (87.20 ± 0.02%). *C. cosyra* and *D. bivittatus* were minority in all incubated fruits. Statistical analysis revealed highly significant differences between percentages of flies ($F = 41404.79$; $df = 8$; $p < 0.001$) (Figure 1).

Northern area

At Korhogo Lataha experimental station of production, species of flies met were *B. invadens* and *C. cosyra*. The species *B. invadens* was majority on three varieties of mangoes: kent (65.55 ± 0.59%), keitt (71.98 ± 1.21%) and amélie (65.29 ± 0.78%). The species *C. cosyra* was minority. Statistical analysis showed highly significant differences between percentages of flies ($F = 14573.14$; $df = 5$; $p < 0.001$) (Figure 1). Four species of fruits flies were indexed on all four localities: *B. invadens*, *C. quinaria*, *C. cosyra* and *D. bivittatus*. *B. invadens* was common to the four localities.

Abundance and distribution of the parasitoids

Southern area

In Abidjan, six species of parasitoids were identified: *Diachasmimorpha tryoni* Cameron, *D. fullawayi* Silvestri, *Fopius arisanus* Sonan, *F. Caudatus* Szepligeti, *F. silvestrii* Wharton and *Psyttalia incisi* Silvestri. These species emerged from two varieties of mangoes (cameronian and polyembryonic). On the cameronian variety, species *D. tryoni* was majority (43.39 ± 1.42 %) and *F. Silvestrii* was minority (4.12 ± 0.56 %). On the mango variety polyembryonic, species *D. tryoni* was also majority (32.73 ± 1.17 %) and *P. incisi* was minority (5.81 ± 0.55 %). Statistical analysis indicated highly significant differences between percentages of parasitoids ($F = 2595.039$; $df = 11$; $p < 0.001$) (**Table 1**).

In Azaguié, six species of parasitoids were indexed: *D tryoni, D. fullawayi, F. arisanus, F. caudatus, F. silvestrii* and *P. lounsburyi* Silvestri. Species *D. tryoni, D. fullawayi, F. arisanus* and *F. caudatus* emerged from all the incubated fruits (papaw, egg yolk, carambola, orange). *F. silvestrii* and *P. lounsburyi* emerged from all fruits except orange. Species *D. tryoni* was majority in the papaw (35.78 ± 1.43 %), the egg yolk (47.40 ± 1.46 %), and the carambola (46.59 ± 1.30 %) while the species *P. lounsburyi* remained minority of all these fruits with respective proportions of 4.79 ± 1.29 %, 2.89 ± 1.33 % and 1.36 ± 0.57 %. In orange, species *D. tryoni* was still dominant (44.33 ± 4.5 %) and the minority species was *F. caudatus* (10.72 ± 2.98 %). In all incubated fruits, species *D. tryoni* remained the dominant species. Statistical analysis revealed highly significant differences between percentages of parasitoids ($F=2784.545$; $df = 23$; $p < 0.001$) (**Table 2**). Species *D. tryoni, D. fullawayi, F. arisanus, F. caudatus, F. silvestrii* and *P. lounsburyi* emerged from hosts *B. invadens* and *C. quinaria*.

Table 1: average number and percentage (%) of the parasitoids listed in the area of Abidjan

Incubated fruits	Species of parasitoids					
	D. tryoni	***D. fullawayi***	***F. arisanus***	***F. caudatus***	***F. silvestrii***	***P. incisi***
	average number (%)	average number (%)	average number (%)	average number (%)	average number (%)	average number (%)
Mangifera indica variety cameronian	35.00±1.73 (43.39±1.42)[a]	12.33±1.52 (15.26±1.30)[ef]	17.00±1 (21.12±0.44)[d]	6.33±0.58 (7.84±0.44)[gh]	3.33±0.58 (4.12±0.56)[i]	6.66±0.58 (8.27±0.74)[g]
variety polyembryonic	30.00±1 (32.73±1.17)[b]	26.33±0.58 (28.73±0.87)[c]	13.00±2 (14.18±2.20)[e]	10.33±1.73 (10.92±1.97)[f]	7.00±1.73 (7.62±1.78)[g]	5.33±0.58 (5.81±0.55)[h]

In the same column and on the same line, the averages followed by the same letters are not significantly different.

Table 2: average number and percentage (%) of the parasitoids listed in the area of Azaguié

Incubated fruits	Species of parasitoids					
	D. tryoni	***D. fullawayi***	***F. arisanus***	***F. caudatus***	***F. silvestrii***	***P. lounsburyi***
	average number (%)	average number (%)	average number (%)	average number (%)	average number (%)	average number (%)
Carica papaya	42.33±1.52	28.00±1	13.33±1.52	15.00±1	14.00±1	5.66±3.21
	(35.78±1.43) b	(23.66±0.95) c	(11.26±1.24) f	(12.67±0.79) ef	(11.83±0.85) ef	(4.79±1.29) i
Richardella campechiana	54.66±1.52	31.00±1	12.00±1	10.33±1.52	4.00±1	3.33±1.52
	(47.40±1.16) a	(26.86±0.98) c	(10.40±0.82) g	(8.96±1.34) gh	(3.47±0.87) j	(2.89±1.33) k
Averrhoa carambola	45.66±1.52	24.33±1.52	16.33±1.52	8.00±2	2.33±0.57	1.33±2.3
	(46.59±1.30) b	(24.84±1.81) d	(16.68±1.73) e	(8.15±1.96) hi	(2.38±0.57) k	(1.36±0.57) k
Citrus sinensis	22.00±2	13.66±1.52	8.66±1.52	5.33±1.52	0	0
	(44.33±4.5) d	(27.52±3.13) g	(17.43±2.90) h	(10.72±2.98) ij	0 l	0 l

In the same column and on the same line, the averages followed by the same letters are not significantly different.

Central area

In lamto, five species of parasitoids were identified: *D. tryoni, D. fullawayi, F. arisanus, F. caudatus* and *P. incisi*. These species emerged from all incubated fruits, except the species *P. incisi* which was absent in papaw. *D. tryoni* was majority in all incubated fruits of this area: papaw (48.49 ± 1.15 %), mango variety polyembryonic (44.44 ± 1.37 %) and mango variety cameronian (50.16 ± 1.28 %). The minority species was *P. incisi* with following proportions: mango variety polyembryonic (8.24 ± 0.55%), mango variety cameronian (10.45 ± 1.25%).

Statistical analysis showed highly significant differences between percentages of parasitoids (F = 15487.47; df= 14; p < 0.001) (**Table 3**). These parasitoids emerged from the hosts' B. *invadens*, *C. cosyra* and *D. bivittatus*.

Northern area

At Korhogo Lataha experimental station of production, six species of parasitoids were indexed: *D. tryoni, D.fullawayi, F.arisanus, F. caudatus, F. vandenboschi* Fullaway and *P. incisi*. These species emerged from all varieties of incubated mangoes (kent, keitt and amélie). Species *D. tryoni* remained majority in all varieties with following proportions: kent (32.20 ± 2.55 %), keitt (30.15 ± 0.99 %) and amélie (31.42 ± 1.67 %). The species *P. incisi* is remained minority on the whole of the fruits with respective proportions of 8.26 ± 2.43 %, 6.86 ± 1.74% and 5.72 ± 0.73 %. Statistical analysis indicated highly significant differences between percentages of parasitoids (F =837.225; df =17; p < 0.001) (**Table 4**). These parasitoids emerged from hosts *B. invadens* and *C. cosyra*.

In the three areas, eight species of parasitoids were identified. They all belong to the order of Hymenoptera and the family of Braconidae. Among these species, *D. tryoni, D. fullawayi, F. Arisanus* and *F. caudatus* were common to all the localities, one common with that of Azaguié and Abidjan (*F. silvestrii*) and one common with the localities of Korhogo and Abidjan (*P. incisi*). One species (*P. lounsburyi*) was specific to the area of Azaguié and another (*F. vandenboschi*) with that of Korhogo.

Table 3 : : average number and percentage (%) of the parasitoids listed in the area of Lamto

Incubated fruits	Species of parasitoids				
	D. tryoni	***D. fullawayi***	***F. arisanus***	***F. caudatus***	***P. incisi***
	average number (%)	average number (%)	average number (%)	average number (%)	average number (%)
Mangifera indica variety polyembryonic	41.33±1.52	19.00±0.57	13.66±0.33	10.66±0.66	7.66±0.33
	(44.44±1.37) c	(20.43±0.99) ef	(14.70±0.76) i	(12.19±0.74) j	(8.24±0.55) k
variety cameronian	49.66±1.52	16.33±1.15	17.66±0.57	5.05±1	10.33±1.15
	(50.16±1.28) b	(16.50±1.18) gh	(17.84±0.44) fg	(5.05±0.98) l	(10.45±1.25) j
Carica papaya	53.66±1.52	20.66±0.57	15.00±1	21.33±1.52	0
	(48.49±1.15) a	(18.67±0.43) de	(13.55±0.90) hi	(19.28±1.48) d	0 m

In the same column and on the same line, the averages followed by the same letters are not significantly different.

Table 4: average number and percentage (%) of the parasitoids listed in the area of Korhogo

Incubated fruits	Species of parasitoids					
	D. tryoni	*D. fullawayi*	*F. arisanus*	*F. caudatus*	*F. vandenboschi*	*P. incisi*
	average number (%)	average number (%)	average number (%)	average number (%)	average number (%)	average number (%)
Mangifera indica variety kent	27.33±1.52	11.33±1.52	10.00±1	10.00±1	19.33±3.05	7.00±2
	(32.20±2.55) [a]	(13.31±1.48) [cd]	(11.78±1.35) [cd]	(11.76±1.06) [cd]	(22.70±3.09) [b]	(8.26±2.43) [d]
variety keitt	23.33±1.52	14.00±1	11.33±1.52	11.66±1.52	11.66±0.58	5.33±1.52
	(30.15±0.99) [ab]	(18.14±1.88) [c]	(14.62±1.49) [cd]	(15.13±2.32) [cd]	(15.10±0.86) [cd]	(6.86±1.74) [e]
variety amélie	25.66±1.52	17.33±1.52	10.33±1.52	11.00±1	12.66±1.52	4.66±0.57
	(31.42±1.67) [a]	(21.22±1.84) [bc]	(12.65±1.85) [cd]	(13.47±1.22) [cd]	(15.52±1.96) [cd]	(5.72±0.73) [e]

In the same column and on the same line, the averages followed by the same letters are not significantly different

Parasitism rates

On the host *B. invadens*, the highest parasitism rate was 44.95 ± 0.71% with the species D. *tryoni,* lowest being 26.36 ± 0.31 % with the species *F. caudatus*. On *C. cosyra*, the highest parasitism rate was 52.47 ± 0.33 % with the species *D. tryoni*, lowest being 34.33 ± 0.39% with the species *F. caudatus* The highest values of the parasitism rate were obtained with species *D. tryoni* and lowest with *F. caudatus*. *D. fullawayi* and *F. arisanus* had intermediate parasitism rates between the extreme values. The host on which the highest parasitism rate were obtained was *C. cosyra* (52.47±0.33; 45.92±0.45; 39.14±0.47; 34.33 ±0.39), more low levels being obtained on *B. invadens* (48.95 ± 0.71; 36.41 ± 0.55; 35.05±0.34; 26.36 ± 0.31). Statistical analysis revealed highly significant differences F= 546.00; df= 7; p < 0.001 (**Table 5**).

DISCUSSION

Four species of fruits flies were listed: *B. invadens*, *C. cosyra*, *C. quinaria* and *D. bivittatus*. *B. invadens* was highly represented in Abidjan, Lamto and Lataha. This abundance could be explained by the presence of many mango orchards in these three areas. In Azaguié, the proportions of *B. invadens* obtained in fruits were important in papaw and orange. Those found in egg yolk and carambolas were low. Proportions of *C. quinaria* observed in egg yolk and carambola were also high. This result could be due to the fact that *C. quinaria* is an indigenous species and that *B. invadens*, species lately appeared, not having found its plant original host, was trying to adapt to the conditions of this area. The species *C. cosyra* was also listed in Abidjan, Lamto and Lataha but lowly compared to *B. invadens*. The predominance of this species would be related to its polyphagous character and high reproductive capacity. That would be also related to interspecific competition between fruit flies and which would be the advantage of *B. invadens*. This argument joined those of Ekesi et al. (2009) and Mwatawala and al. (2009) who reported the dominance of *B. invadens* on *C. cosyra*. These results confirmed that of Hala (2006) who reported that *B. invadens* was the dominant species of fruit flies in Ivorian territory. These results confirmed also those of N'Dépo et al. (2009; 2010) who indicated that the species *B. invadens* had supplanted the species *C. cosyra* that caused 85% damage on mangoes in northern Côte d'Ivoire. The species *C. quinaria* was listed in Azaguié. This result differs from those of N'Dépo et al. (2009)

Tableau 5: parasitism rate of the parasitoids on mango variety Kent in Korhogo in northern Côte d'Ivoire

Species of parasitoids	Species of fruit flies			
	B. invadens		*C. cosyra*	
	Average number of parasitoids	Parasitism rate (%)	Average number of parasitoids	Parasitism rate (%)
D. tryoni	31.90 ± 1.26	48.95 ± 0.71 [b]	27.00 ± 0.83	52.47 ± 0,33 [a]
D. fullawayi	26.10 ± 1.64	36.41 ± 0.55 [e]	23.80 ± 1.32	45.92 ± 0.45 [c]
F. arisanus	25.05 ± 1.07	35.05 ± 0.34 [f]	20.10 ± 0.99	39.14 ± 0.47 [d]
F. caudatus	19.05 ± 0.92	26.36 ± 0.31 [g]	18.25 ± 0.99	34.33 ± 0.39 [f]

In the same column and on the same line, the averages followed by the same letters are not significantly different.

who did not report the presence of this species in the locality.

Eight parasitoid species were identified. They all belong to the order Hymenoptera. This result joined those of Hawkins et al. (1997) who indicated that the Hymenoptera are majority (67%) among insect parasitoids. Also, Rousse (2007) reported that at least 82 species of parasitoids were collected from Tephritidae. Four of the eight indexed species are common to the three agro-ecological areas: *D. tryoni, D. fullawayi, F. arisanus* and *F. caudatus*. The two species of the *Diachasmimorpha* genus were most abundant in the hosts, mainly *D. tryoni*. The species *D. tryoni* could be indigenous parasitoid which propagated to the favor trade. The dominance of *D. tryoni* would be related to its acclimatation to the conditions of the rearing environment (Hurtrel, 2000, Lopez et al. 2003; Quilici et al., 2004). As to the species *F. arisanus* and *F. caudatus*, their low abundance would be to the fact that our breeding conditions were higher than the climatic conditions of the fairly warn areas to which these species would be adapted better (Rousse and al, 2006; Rousse, 2007). Their introduction, probably recent with their host *B. invadens,* could be also evoked (Kadio, 2009). Indeed, *B. invadens* would be one of the preferred hosts of *F. arisanus* (Vargas and al, 2002). Also, the predominance of *F. arisanus* within the guild of Opiinae parasitoïdes of Tephritidae was confirmed by several authors (Bautista and Harris, 1997; Vargas and al., 2002; Wang and al., 2003). However, in Philippines, Palacio and al. (1991) indicated that *F. arisanus* can be supplanted by *D. longicaudata*. This explanation may be related to Côte d'Ivoire where *D. tryoni*, species close to *D. longicaudata*, seems to currently be dominating *P. lounsburyi* was a species specific to Azaguié. It was lowly represented there, probably, because of a competition between the various species of parasitoids. Also, fruit flies of this locality would have become the secondary hosts of these parasitoids. In our experimental conditions, parasitism rates of parasitoids were obtained with species of the genus *Diachasmimorpha.* This result joined that of Wong and al. (1991) who reported that D. *tryoni* was efficient to suppress a mediterranean fruit fly. Parasitism rates were higher on *C. cosyra* than on *B. invadens.* This difference could be explained by the fact that *C. cosyra* would

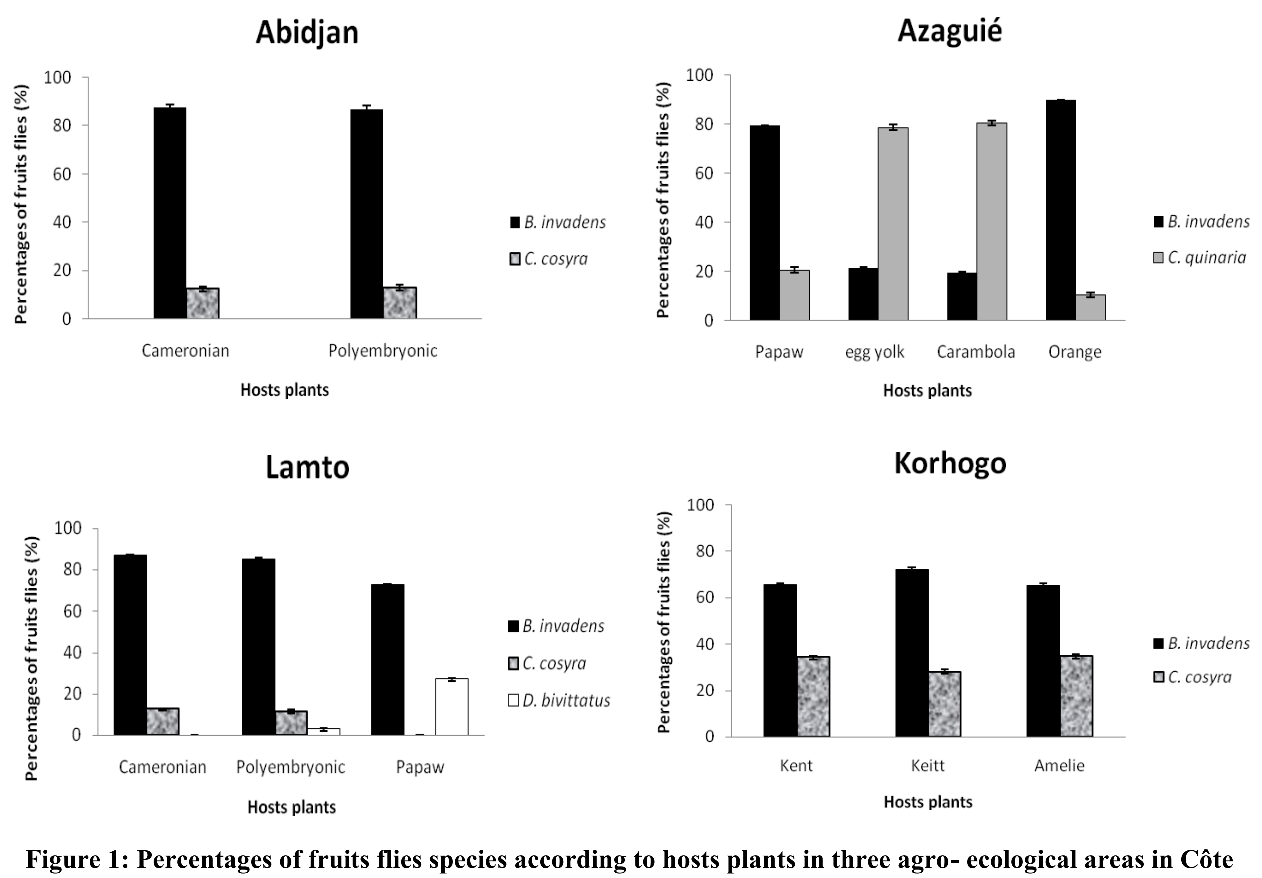

Figure 1: Percentages of fruits flies species according to hosts plants in three agro- ecological areas in Côte d'Ivoire

be the original host of parasitoids in our study area. The highest reproductive capacity of *B. invadens* could also be considered. A similar observation was made by Ekesi and al., (2006) who reported that the fecundity of *B. invadens* was higher than that of *C. cosyra.* The proportion of eggs infested at the first fly species was lower than the second. As immature stages of *C. cosyra* would be more conducive to the development of parasitoids.

CONCLUSION

In four localities corresponding to three areas (south, center and north) of the Côte d'Ivoire, four species of fly host of parasitoids were listed: *B. invadens, C. cosyra*, *C.quinaria* and *D. bivittatus*. A great variety of parasitoids of fruits flies exists in Côte d'Ivoire. On the whole, eight species were identified (*D. tryoni, D. fullawayi, F. arisanus*, *F. caudatus, F. silvestrii, F. vandenboschi, P. lounsburyi* and *P. incisi)*. Species *D. tryoni* was present in all incubated fruits and was most dominant. The study of parasitism revealed rates varying from 26.36 ± 0.31% to 48.95 ± 0.71% on *B. invadens* and from 34.33 ± 0.39% to 52.47 ± 0.33% on *C. cosyra*. The greatest rate of parasitism was recorded with species *D. tryoni* on two hosts. Species *D. tryoni* seemed to be the most suitable parasitoid in the fight against the fruits flies in Côte d'Ivoire. A mass breeding of these insects could be under consideration in a specialized structure in order to guarantee the medical quality of the fruits.

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