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Preliminary inventory of parasitoids associated with fruit flies in mangoes, guavas, cashew pepper and wild fruit crops in Benin

Jean-François Vayssières · Robert Wharton · Appolinaire Adandonon · Antonio Sinzogan

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Abstract Fruit flies are pests of great economic importance due to their quarantine pest status and losses recorded in West Africa. An inventory of parasitoids associated with fruit flies in mangoes, guavas, cashew, pepper and major wild fruit crops was carried out in northern-central Benin in 2005, 2006, and 2008. Tephritid parasitoids reared from field-collected fruits belonged to three families: Braconidae (97.2%), Eulophidae (1.6%) and Pteromalidae (1.2%). *Fopius caudatus* (Szépligeti) accounted for 73.8% of all the parasitoids and therefore was the most abundant and widely distributed parasitoid. The parasitism rate was 7.7%, with the highest recorded in wild fruit crop habitat. *Ceratitis cosyra* (Walker) (77%) was the fly host most commonly reared from fruits that produced *F. caudatus*. The recently introduced pest *Bactrocera invadens* Drew Tsuruta and White was rarely parasitized and only by *Pachycrepoideus vindemmiae* (Rondani) (Hymenoptera: Pteromalidae) at this time. This is the first report of the inventory of one native parasitoid species from *B. invadens* in Africa, especially in West Africa.

Keywords Biological control · *Bactrocera invadens* · *Ceratitis* spp. · Tephritidae · Braconidae · Eulophidae · Pteromalidae

Introduction

Fruit flies (Diptera: Tephritidae) are among the most economically important pests of edible fruits worldwide (Wharton 1989; Billah et al. 2008a; Vayssières et al. 2008) and are also considered to be pests of quarantine importance. Their control has been the focus of many fruit fly research programs, especially for biological control through the use of parasitic Hymenoptera (Clausen 1978; Waterhouse 1993; Ovruski et al. 2000). Numerous studies have demonstrated the feasibility of the use of parasitoids for fruit fly suppression (Clausen et al. 1965; Harris et al. 2000; Sivinski et al. 2000; Vargas et al. 2007). Parasitoids from Africa, including several species of *Psyttalia* and *Fopius*, have attracted much interest for use as biological control agents (Silvestri 1913; Messing 1999; Wharton et al. 2000; Lopez et al. 2003; Sime et al. 2006; Billah et al.

This work is part of a regional program on fruit fly control strategies in West Africa, coordinated by Dr Jean-François Vayssières, IITA-Benin. We think it is important to first inventory the native parasitoid species before undertaking the fruit fly biocontrol and especially before carrying out any introduction of exotic species of parasitoids.

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J.-F. Vayssières (✉) · A. Adandonon · A. Sinzogan
IITA-CIRAD, Biocontrol Unit for Africa, 08 BP 09 32, Cotonou, Benin
e-mail: j.vayssieres@cgiar.org

R. Wharton
Department of Entomology, Biological Control Facility, Texas A.M. University, College Station, TX, USA

2008b). One species, *Psyttalia concolor* (Szépligeti), has been widely released throughout the Mediterranean region through various augmentative biological control programs (Raspi 1995).

In tropical regions, mango (*Mangifera indica* L.) is a particularly important tropical fruit for Sub-Saharan African national and regional economies, as well as for exports (Vayssières et al. 2008). Mangoes are attacked by both native and introduced tephritid fruit flies which wreak great economic devastation in both East Africa (Ekesi et al. 2006) and West Africa (Vayssières et al. 2008). Before 2003, native tephritid pests such as *Ceratitis cosyra* (Walker) destroyed an average of 40% of the total mango crop produced yearly in Africa (1.9 Mt) (Lux et al. 2003). In Benin for instance, at the end of the crop year, in 2005 as in 2006, over 75% of production was lost due to fruit flies (Vayssières et al. 2009). The arrival and dispersion of *Bactrocera invadens* Drew, Tsuruta and White throughout West Africa in 2004 has considerably worsened the damage to marketable fruit crops, especially mangoes (Vayssières et al. 2005).

The African continent has been the focus of several biological control programs, with a particular focus on collections and surveys of parasitoids for export to other regions to control pests such as Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) and the olive fly, *Bactrocera oleae* (Rossi) (Neuenschwander 1982; Steck et al. 1986; Wharton et al. 2000; Mkize et al. 2008; Wang et al. 2009; Rugman-Jones et al. 2009). Although some of the previous surveys have included Benin and adjacent countries (Silvestri 1914; Steck et al. 1986), mangoes were not included among the fruits sampled, and throughout Sub-Saharan Africa, there has been little effort to date to survey natural enemies attacking tephritid pests of mangos. The objectives of this preliminary study were (i) to make an inventory of fruit fly parasitoids in areas of large mango productions in Benin, and (ii) to determine the overall parasitism rate and the pest control potential of these Hymenopteran parasitoids to provide baseline data for future biological control efforts.

Materials and methods

Sampling sites

The most numerous and largest orchards (75% of Beninese mango orchards), in terms of area and diversity with 29 mango cultivars (Vayssières et al. 2008), are in Borgou. There we can find the greatest plant diversity as this zone is at the boundary of the Northern Guinean savannah and the Southern Sudanian savannah of Benin (Vayssières et al. 2008). The climate type of this zone is Sudanian, characterized by unimodal rainfall (1000–1100 mm yearly) with an annual mean temperature ranging from 26°C to 27°C. The rainy season usually starts at the end of April and lasts for six months until the end of October. The trials were conducted in this area at four different locations, Tchaourou, Parakou, N'Dali and Bembéréké, of this Borgou Department.

Fruit crop species

Fruits were sampled from different mango (*M. indica*) cultivars, namely, cv Ruby, Alphonse de Goa, Brooks, Eldon, Kent, Keitt, Dabshar Drahnet, Smith, Zill, Gouverneur, Améliorée du Cameroun, Atacora and ungrafted local. These cultivars were selected for the study because they were present in almost all selected orchards. Other fruit crop species were also included in the fruit sampling and concerned wild fruit crop species, namely, *Sarcocephalus latifolius* (Smith) Bruce (Rubiaceae), *Vitellaria paradoxa* Gaertn. (Sapotaceae), *Annona senegalensis* Pers. (Annonaceae), and cultivated edible species, namely, *Anacardium occidentale* L. (Anacardiaceae), *Psidium guajava* L. (Myrtaceae), *Citrus sinensis* L. (Rutaceae) and *Capsicum annuum* L. (Solanaceae). These fruit species were chosen because they grow in very close proximity to these mango orchards. We have very similar habitats around these mango orchards.

Fruit sampling and observation in the laboratory

To determine the fly species and associated parasitoids in the selected fruit habitats, all mango cultivars as well as other cultivated and wild fruit crops encountered were sampled in a two-year preliminary survey during the fruit season in 2005 and 2006 and also in a more exhaustive survey in 2008. Samples were not taken throughout the year but only during seasons when the mentioned host fruits were available to sample (though other fruit hosts might have been available to the flies at other times of the year). In 2005, no survey samples were taken in January, February, September, October, November, December. In 2006, no survey samples

were taken in January, August, September, October, November, December. In 2008, no survey samples were taken in January, February, March, August, September, October, November, December. In the preliminary survey, fruits at prematurity and maturity stages were randomly sampled each week according to availability and reared in the laboratory to record the fly species and associated parasitoids. In the more exhaustive quantitative survey, data on fruit infestation rate, parasitism rate and parasitoid abundance were obtained.

Fruit samples were brought to the laboratory, individually weighed, counted and classified by cultivar, date and sample site. After being allocated a sequence number, they were placed for observation onto mesh supports mounted on basins filled with wet sand, in which larvae emerging from the fruits could drop and metamorphose into pupae (Vayssières et al. 2007). For each cultivar, the fruit samples were individualized according to the site and their sampling date for easy referencing of the sample origin. At five-day intervals, the sand covering the bottom of the containers was sieved to collect the pupae. The pupae, collected with flexible tweezers, were then put with a sequence number into small hatchery boxes lined with moist blotting paper. Newly emerged adults were removed every three days. Fruit fly identifications were made by J.F. Vayssières but confirmed by M. De Meyer in some cases. Parasitoid identifications were made by R. Wharton in the laboratories of Texas A&M University, USA. Voucher specimens are deposited in the Insect Collections in Texas A&M University with references numbers RVA 1643-1671, RVA 1772-1798, RVA 2062-2147.

Percent parasitism was calculated as $a/(a + b) \times 100$, where a = number of recovered parasitoids and b = number of emerged adult flies in each sample (Steck et al. 1986). Infestation rate was calculated as the number of pupae per kg fruit. Log10 $(x + 1)$ transformation was used on percentage data to stabilize the variance and normalize the data. Analysis of variance was performed using the general linear model procedure and mean separations were done using the Student–Newman–Keuls test (SAS 2003).

Host/parasitoid associations are based on assumptions that parasitoids reared from a fruit sample were attacking only hosts that were also reared as adults from that sample, with attack rate on different hosts based on percent of hosts in the sample. We can consider that this is only an approximation, and that many factors, such as the ability of parasitoids to select preferred hosts and encapsulation by unsuitable hosts, increase the level of uncertainty in this regard.

Results

The numbers of sampled fruits per crop species per cultivar during the full survey in 2008 are shown in Table 1. There were 810 fruits collected every week, with a total of 6970 fruits collected and held in the laboratory for rearing and emergences of insects. Six species of parasitoids belonging to three families of Hymenoptera were reared from survey samples (Table 2): Braconidae [*Fopius caudatus* (Szépligeti), *Psyttalia cosyrae* (Wilkinson), *P. perproxima* (Silvestri), and *Diachasmimorpha fullawayi* (Silvestri)], Eulophidae (*Tetrastichus giffardianus* Silvestri) and Pteromalidae (*Pachycrepoideus vindemmiae* (Rondani). The majority of the parasitoids were braconids (97.2%). The most abundant parasitoid was *F. caudatus* (73.8%) followed by *Psyttalia* spp (21.8%) (with *P. perproxima* 19.5% and *P. cosyrae* 2.3%). These proportions are based on the total samples studied (data not shown). *Fopius* and *Psyttalia* were recorded in all fruit crop habitats except those of *P. guajava and C. annuum*. The occurrence rate for all other parasitoid species combined was less than 5%.

Factors such as the location (Fig. 1), habitat (fruit crop species) (Table 2, Fig. 2), fruit fly species (Table 3) and fruit seasons (Table 4) determine the occurrence and parasitism rate of the parasitoid species. Thus, parasitism rate was the highest ($F = 4.745$, df = 3, 96; $P = 0.024$) in Bembéréké (8.94%) while the lowest rate was recorded in Parakou (3.21%) (Fig. 1). Infestation and parasitism rates were also cultivar-dependent (Table 2). Comparing all fruit

Table 1 Number of trees and fruit samples during collection at the different sites in 2008

Fruit crop species	Total fruit samples
M. indica	1000
P. guajava	930
C. sinensis	200
V. paradoxa	1200
A. senegalensis	2350
S. latifolius	1290

Table 2 Number of pupae per kg fruit as infestation rate, fruit fly species, parasitism rate and associated parasitoid species recovered from different mango cultivars and other fruit crops in northern-central Benin in 2005, 2006 and 2008

Habitat (fruit crop species)	Number of pupae per kg fruit	Parasitism rate (%)	Fruit size (cm)	Fruit fly species recovered	Parasitoid species
M. indica/cv Ruby	22.70 ± 5.82 cd	0.03 ± 0.02 a	Long = 9 × larg = 6	*C. cosyra; B. invadens*	*F. caudatus*
M. indica/cv Alphonse	30.90 ± 10.20 e	11.53 ± 3.74 d	Long = 15 × larg = 8	*C. cosyra; B. invadens*	*F. caudatus; P. vindemmiae*
M. indica/cv Brooks	23.47 ± 10.10 de	0.09 ± 0.03 a	Long = 13 × larg = 8	*C. cosyra; B. invadens*	*F. caudatus; P. perproxima; P. vindemmia; D. fullawayi P.cosyrae;*
M. indica/cv Eldon	14.42 ± 2.29 b	3.81 ± 1.15 ab	Long = 13 × larg = 9	*C. cosyra; C. quinaria; C. silvestrii; C. capitata; B. invadens*	*F. caudatus; P. cosyrae*; *P. perproxima*
M. indica/cv Kent	24.57 ± 4.32 de	9.12 ± 3.65 cd	Long = 15 × larg = 12	*C. cosyra; C. capitata; B. invadens*	*F. caudatus; P.cosyrae*; *P. perproxim*a
M. indica/cv Keitt	26.14 ± 5.61 de	5.14 ± 1.64 bc	Long = 16 × larg = 13	*C. cosyra;*	*F. caudatus;*
M. indica/Dabschar	5.20 ± 1.55 a	0.06 ± 0.00 a	Long = 16 × larg = 15	*C. cosyra; B. invadens*	*P. perproxima*
M. indica/cv Smith	15.00 ± 2.55 bc	0.07 ± 0.01 a	Long = 16 × larg = 9	*C. cosyra; B. invadens*	*F. caudatus; P. cosyrae; D. fullawayi*
M. indica/cv Zill	3.55 ± 1.70 a	0.02 ± 0.00 a	Long = 12 × larg = 10	*C. cosyra*	*F. caudatus*
M. indica/cv Gouverneur	27.01 ± 17.0 de	11.42 ± 10.60 d	Long = 11 × larg = 9	*C. cosyra; C. quinaria; C. silvestrii; B. invadens*	*F. caudatus*
M. indica ungrafted	5.07 ± 0.72 a	1.89 ± 1.63 a		*C. cosyra*	*P. perproxima*
P. guajava	68.47 ± 13.92 g	1.29 ± 0.51 a	Diam. = 5	*C. cosyra; B. invadens*	*T. giffardianus*
S. latifolius	48.23 ± 6.45 f	28.90 ± 1.84 f	Diam. = 4	*C. cosyra; B. invadens,*	*F.caudatus*
V. paradoxa	22.35 ± 4.99 bcd	7.20 ± 5.31 bcd	Diam. = 4.5	*C. cosyra; C. quinaria; C. silvestrii; B. invadens*	*F. caudatus; P. cosyrae; P. perproxima*
C. annuum	48.26 ± 8.00 f	5.82 ± 1.59 bc	Diam. = 3	*C. capitata*	*D. fullawayi; T. giffardianus*
A. senegalensis	121.21 ± 30.28 h	20.40 ± 2.37 e	Diam. = 4	*C. cosyra; B. invadens*	*F. caudatus*; *P. perproxima*
A. occidentale	4.30 ± 1.07 a	1.34 ± 0.52 a	Diam. = 6	*B. invadens; C. cosyra*	*P. vindemmiae*
Average	30.05 ± 7.10	6.36 ± 1.96			

In the same column, values followed by different letters are significantly different ($P < 0.05$) according to Student–Newman–Keuls test. Each column information is linked to column of habitat (first column) only and not to each other. Values are means ± SE

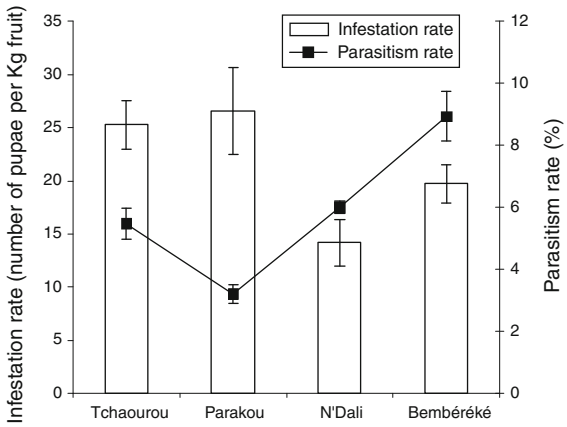

Fig. 1 Mango infestation and parasitism rate of fruit fly species in four mango production areas in northern-central Benin. Error bars plotted on figure are SE values

crops included in the study, cultivated fruit crops showed the significantly ($F = 3.760$; df = 16, 248; $P = 0.041$) lower parasitism rates as compared to wild fruit crop species such as *A. senegalensis* and *S. latifolius*. For instance, the parasitism rate recorded in *M. indica* habitat was 5.9% (irrespective to the cultivars) which was significantly ($F = 3.760$; df = 16, 248; $P = 0.041$) lower than that of wild fruit crop species (Fig. 2). However, the parasitism rate in general was less than 30% (Fig. 2). No correlation was detected between fruit weight and infestation rate ($r^2 = 0.157$, $F = 1.045$, df = 1, 264; $P = 0.958$) or

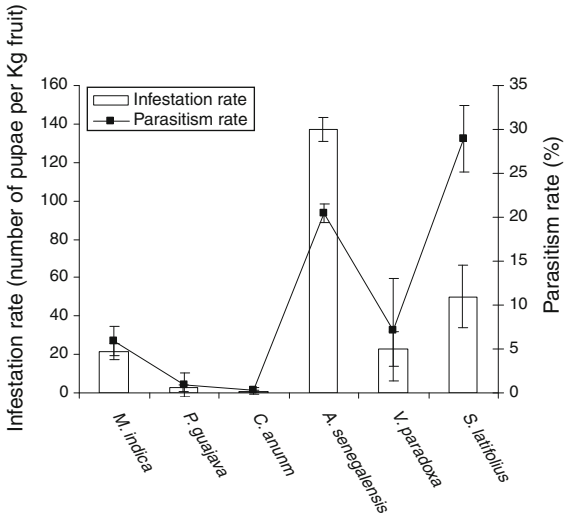

Fig. 2 Infestation and parasitism rate of fruit fly species in relation to fruit crop species in northern-central Benin. Error bars plotted on figure are SE values

fruit weight and parasitism ($r^2 = 0.101$, $F = 0.495$, df = 1, 264; $P = 0.186$). However, higher ($F = 19.325$; df = 16, 248; $P = 0.036$) parasitism rates are recorded from wild fruits such as *A. senegalensis* (20.40 ± 2.37) and *S. latifolius* (28.90 ± 1.84), which also had the highest ($F = 19.325$; df = 16, 248; $P = 0.036$) infestation rates (Table 2).

For the fruit fly species/parasitoid samples identified, the fruit fly host most frequently reared from fruit samples that produced parasitoids was *C. cosyra* (77% of all flies reared from fruit samples producing tephritid parasitoids were *C. cosyrae*). The least parasitized were *B. invadens* (5.1%), *C. quinaria* (Bezzi) (5.1%) and *C. silvestrii* (0.8%) (Table 3). *C. cosyra*, the most damaging fruit fly pest in northern-central Benin, is mostly attacked by *F. caudatus* as its principal parasitoid. It is also secondarily parasitized by *P. cosyrae* and to a lesser extent by *D. fullawayi* (Table 3). *F. caudatus* and *P. cosyrae* also appeared to be the principal parasitoids of *C. quinaria*. In the samples processed to date, *C. silvestrii* Bezzi was only parasitized by *P. perproxima* and *B. invadens* was only parasitized by *P. vindemmiae*. Our preliminary data suggest that parasitism rates are the highest in June (Table 4).

Discussion

To our knowledge, this is the first inventory of parasitoid species from cultivated mangoes in Benin and provides critical baseline data for future conservation or introduction of parasitoids in biological control programs. The six parasitoid species have been reported from West Africa previously (Vayssières et al. 2002). There are several species of *Psyttalia* in the Sub-Saharan region that are difficult to differentiate (Rugman-Jones et al. 2009). The species reared in this program include both long-ovipositor forms (*P. cosyrae*) and some with shorter ovipositors that we are calling *P. perproxima. P. perproxima* was originally described from Benin from fruits infested by tephritids (Silvestri 1913), and our material fits the original description of this species. However, because the species of *Psyttalia* are difficult to discriminate, it is possible that more than two species of *Psyttalia* are included in our samples, including either *P. concolor* or the nearly identical *P. humilis* (Silvestri) (Rugman-Jones et al. 2009). *F. caudatus* was also recorded by

Table 3 Number and percentage of the various parasitoid species emerging from Tephritidae pupae collected from fruits picked from different orchards in northern-central Benin

Fruit flies	*F. caudatus*		*P. perproxima*		*P. cosyrae*		*T. giffardianus*		*D. fullawayi*		*P. vindemmiae*		All species	
	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%
C. cosyra	73	70.2	0	0.0	22	21.1	2	1.9	7	6.8	0	0.0	104	77.0
C. capitata	0	0.0	0	0.0	0	0	11	68.8	5	31.2	0	0.0	16	12.0
C. quinaria	3	42.9	1	14.2	3	42.9	0	0.0	0	0.0	0	0.0	7	5.1
C. silvestrii	0	0.0	1	100	0	0.0	0	0.0	0	0.0	0	0.0	1	0.8
B. invadens	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	7	100	7	5.1

Table 4 Count numbers of parasitoid species recovered from different fruit crop species in relation to periods of occurrence in northern-central Benin

Period (months)	*F. caudatus*	*P. perproxima*	*P. cosyrae*	*T. giffardianus*	*D. fullawayi*	*P. vindemmiae*
March 2005	–	1	–	–	–	–
April 2005	–	2	–	–	–	–
May 2005	10	1	2	–	2	–
June 2005	11	15	11	–	–	7
July 2005	–	–	–	–	–	–
August 2005	3	–	–	2	–	–
February 2006	–	–	–	–	–	4
March 2006	–	–	–	–	–	–
April 2006	–	–	2	–	–	–
May 2006	20	–	1	–	5	–
June 2006	–	–	–	–	–	–
July 2006	54	–	3	11	5	–
April 2008	–	–	–	–	–	–
May 2008	89	9	–	–	–	–
June 2008	431	135	–	–	1	–
July 2008	–	–	–	–	–	–

In 2005, no survey samples were taken in January, February, September, October, November, December

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In 2008, no survey samples were taken in January, February, March, August, September, October, November, December

Silvestri (1913) from Benin and *F. silvestrii* was originally described by Wharton (1987) from West Africa (Togo) and Central Africa (Cameroon).

The majority of the recorded parasitoids from all the samples in the current study were braconids and *F. caudatus* was the most abundant and widely distributed, followed by *Psyttalia* spp. *F. caudatus* was recorded in different locations and from different fruit crops. Despite the numerous fruit fly species, such as *C. cosyra, C. silvestrii, C. quinaria, C. capitata and B. invadens*, recovered from fruits in the current experiment, *F. caudatus* was recovered most frequently from *C. cosyra*-infested fruits and secondarily from *C. quinaria*-infested fruits. These species might therefore be the preferred hosts for *F. caudatus* in our samples. As reported earlier, fruit fly parasitoids, in general, may develop on several tephritids but they often have a specific, preferred host (Wharton 1989). This was the case in Hawaii where *Fopius arisanus* (Sonan), a related species, caused substantial reduction of the host populations when released against the introduced pest *Bactrocera dorsalis* (Hendel), but became the major parasitoid of a previously introduced pest, *C. capitata* (Vargas et al. 2007). In the

current study and for the fruit fly/parasitoid samples identified so far, the native parasitoid *F. caudatus* was not recovered from fruits infested by certain fruit flies such as *C. capitata, C. silvestrii and B. invadens*. Further controlled laboratory setting experiment will confirm whether these fruit fly species do not permit the development of *F. caudatus*.

As for any other insect, parasitoid survival and hence parasitism rate can be influenced by abiotic factors such as temperature (Rousse et al. 2005) and relative humidity. Therefore, samples from different agro-ecological zones may yield different recoveries of parasitoids. In our current work, the studied locations were in a similar agro-ecological zone and as such the climatic conditions might not be the driving factor explaining the difference found among samples in terms of recovered parasitoids and parasitism rate. Rather, the phenological stage of the fruit crops and the probable proximity of wild fruit species in each location may be an important factor influencing the occurrence of the parasitoids. The most infested phenological stages are mainly the premature and mature fruits hosting eggs and larvae of Tephritidae. Wild fruit data of *S. latifolius* and *A. senegalensis* are indeed a kind of "parasitoid-pond" with higher parasitism rates of 28.9% and 20.4%, respectively (Table 2). During the current survey, samples were not taken throughout the year but only during seasons when the mentioned host fruits were available to sample (other fruit hosts might have been available to the flies at other times of the year). Most of the parasitoids were recovered in May–June or July, like their host flies, and this period coincided with the rainy season and the second half of the mango season.

The overall mean parasitism rate considering all samples was $6.36 \pm 1.96\%$ with the lowest rate $0.02 \pm 0.00\%$ recorded in mango cv Zill. Previous hypotheses have attributed low rates of parasitism in part to physical difficulties in locating immature stages of fruit flies within large fruits (Sivinski et al. 2000; Wang et al. 2009). Our results showed the lowest parasitism rate recorded from *M. indica* cultivars but the highest from the wild fruit crop species habitats such as *A. senegalensis* and *S. latifolius* where larvae are closer to the fruit surface.

In Table 2 we show that small size of fruits can be linked with higher parasitism rate than large size as mango fruits (with many cv). There was a negative correlation ($y = -0.5614x + 1.8683$; $r^2 = 0.781$; $F = 7.135$; df = 1, 32; $P = 0.034$) between the fruit size and the parasitism rate. These observations could support Sivinski's and Wang's work on ovipositor length vs fruit size. If it is true for *A. senegalensis* it is not evident for *S. latifolius* which hosts a large amount of *F. caudatus*. As they oviposit in fly eggs which are placed not so far from the surface of the fruit, then, fruit size is not really a problem for *Fopius* species. Anyway, we can generally say that we have a greater number and diversity larval parasitoid obtained from small wild fruits (*A. senegalensis, V. paradoxa*) than large cultivated grafted mangoes (Brooks, Dabschar, Smith, Zill).

On the other hand, cultivated crop habitats such as mango orchards may constitute unfavorable conditions due to human interventions (cultural practices, insecticide application) that negatively impact parasitoids. This is consistent with the report from Hernández-Ortiz et al. (2006). These authors attributed low level of parasitism in his study to probable orchard management practices, in which periodic pesticide use could have a negative impact on parasitoid populations. Studies carried out in Brazil reported similar species diversity and levels of parasitism (Uchôa-Fernandes et al. 2003). In either case, our data are consistent with earlier findings concerning parasitoid abundance in wild vs cultivated settings (Aluja and Liedo 1986; Vargas et al. 1993; Sivinski et al. 2000; Hernández-Ortiz et al. 2006) and indicate a host habitat preference for the wild fruit crop habitat for the dominant parasitoid species reported here. The presence of these wild hosts is of great importance for IPM in general, and especially for biological control (Vayssières et al. 2002). Higher infestation rates in wild fruits can serve as a source for infestations in cultivated fruits at least seasonally. However, these wild plants are also a potential reservoir for the development of the parasitoids throughout the year.

In a given fruit crop production area, there is always a diverse assemblage of native fruit fly parasitoids, and our samples indicate that northern-central Benin is no exception. Yet, the efficacy of this parasitoid assemblage in controlling tephritid pests is low as indicated by the high infestation rate with low parasitism rate. Our most abundant species, *F. caudatus*, exhibited generally low levels of parasitism overall, and was not recovered from the introduced

pest *B. invadens*. This very low rate of parasitism by natives may justify the introduction of a non-native such as *F. arisanus* that is known to be very effective against many fruit flies (Haramoto and Bess 1970; Rousse et al. 2005, 2006) including members of the *B. dorsalis* complex. For example, *F. arisanus* has been introduced for a classical biological control program by CIRAD (International Centre of Agricultural Research for Development) into Reunion Island against *B. zonata*. Most recently, *F. arisanus* proved very successful when introduced to Tahiti (Vargas et al. 2007) against *B. dorsalis*. *F. arisanus* has been reported to parasitize 21 tephritid species and to develop, with variable success, on 18 of them (Rousse et al. 2005). Therefore, *F. arisanus* could similarly be effective against the damaging fruit flies in West Africa especially *B. invadens*.

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Author Biographies

Dr Robert Wharton Texas A&M University, is a close collaborator of the program and has long experiment in biocontrol of fruit flies. He has written many scientific articles on this topic.

Dr Appolinaire Adandonon is assisting the Coordinator in managing activities of the regional program.

Dr Antonio Sinzogan is assisting the Coordinator in managing activities of the regional program.