Preliminary inventory of fruit fly species (Diptera, Tephritidae) in mango orchards in the Niayes region, Senegal, in 2004

Jean-François Vayssières[1*], Henri Vannière[2], Pap' Sam Gueye[3], Oumar Barry[3], Alhousseynou Moctar Hanne[4], Sam Korie[5], Abdoulaye Niassy[†], MBaye Ndiaye[4], Gilles Delhove[6]

[1] CIRAD, Persyst, UPR HortSys, 34398 Montpellier, France ; IITA, Cotonou, Benin
j.vayssieres@cgiar.org

[2] CIRAD, Persyst, UPR HortSys, TA B-103 / PS 4, 34398 Montpellier, France

[3] CERES-LOCUSTOX, FAO, BP 3300, Dakar, Senegal

[4] DPV, BP 20054, Thiaroye, Dakar, Senegal

[5] IITA, 08 BP 0932, Tri Postal, Cotonou, Benin

[6] PIP / COLEACP, 98 Rue du Trône, 1050, Brussels, Belgium

** Correspondence and reprints*

Received 1 December 2009
Accepted 3 August 2010

Fruits, 2011, vol. 66, p. 91–107

DOI: 10.1051/fruits/2011002
www.fruits-journal.org

Resumen Español, p. 107

Preliminary inventory of fruit fly species in mango orchards in the Niayes region, Senegal, in 2004.

Abstract — **Introduction**. Knowledge of tephritid diversity in Senegal was poor before 2004, so PIP-COLEACP and CIRAD, in collaboration with Cérès-DPV, carried out, in 2004, trapping for preliminary detection of fruit flies in six orchards in the Niayes zone. **Materials and methods**. We selected three mixed mango orchards and three homogeneous mango orchards in this zone. In each orchard, we used three attractants: Terpinyl acetate (Ter), Trimedlure (Tri) and Torula (Tor). Traps were serviced weekly. **Results**. We captured 77 642 fruit flies in more than 4 months including mango season; they were represented by 18 identified fly species, including ten *Ceratitis*, six *Dacus* and two *Bactrocera* species. Two very serious pests were identified with the confirmation of *Bactrocera cucurbitae* (Coquillett) for cucurbit crops and the detection of *B. invadens* Drew Tsuruta & White for fruit crops. The two most abundant species of *Ceratitis* were *C. cosyra* and *C. silvestrii*. **Discussion**. We captured more fruit fly species in mixed mango orchards than in homogeneous mango orchards. *Bactrocera invadens* was also more abundant in mixed orchards, probably because of its polyphagous status. This new invasive species, *B. invadens*, can have many hosts in mixed mango orchards, enhancing its breeding potential. **Conclusion**. Effective management to deal with this alien species requires: (i) improvement of basic and applied research; (ii) an effective IPM package; (iii) an area-wide management approach; (iv) a sub-regional effort on the part of researchers, extension services, growers, exporters, farming associations and the different actors in fruit value chains (mainly mango).

Senegal / *Mangifera indica* / Tephritidae / *Ceratitis* / *Dacus* / *Bactrocera cucurbitae* / *Bactrocera invadens* / biodiversity / trapping / trapping baits

Inventaire des espèces de mouches des fruits dans les vergers de manguiers de la zone des Niayes au Sénégal, en 2004.

Résumé — **Introduction**. Au Sénégal, la liste des espèces de mouches des fruits recensées était relativement mal connue avant 2004. C'est la raison pour laquelle le PIP-COLEACP et le CIRAD, avec la collaboration du Cérès-DPV, ont commencé, en 2004, à placer des pièges de détection des mouches des fruits dans six vergers de manguiers situés dans les Niayes. **Matériel et méthodes**. Nous avons sélectionné trois vergers mixtes (à dominance manguiers) et trois vergers de manguiers monospécifiques dans cette zone. Dans chaque verger, trois types d'attractifs pour Tephritidae ont été utilisés : le terpinyl acétate (Ter), le trimedlure (Tri), et le torula (Tor). Les pièges ont été relevés chaque semaine. **Résultats**. Nous avons capturé 77 642 mouches des fruits en plus de 4 mois de piégeage incluant la compagne mangue ; parmi les 18 espèces de mouches de fruits identifiées, nous avons trouvé dix espèces de *Ceratitis*, six espèces de *Dacus* et deux espèces de *Bactrocera*. Au sein du genre *Bactrocera*, nous avons identifié deux espèces de ravageurs de grande importance économique : nous avons confirmé la présence de *B. cucurbitae* pour les cultures de Cucurbitaceae et nous avons détecté celle de *B. invadens* pour les cultures fruitières. Les principales espèces de cératites présentes ont été *Ceratitis cosyra* et *C. silvestrii*. **Discussion**. Nous avons capturé davantage d'espèces de mouches des fruits dans les vergers mixtes de manguiers que dans les vergers homogènes. De même nous avons capturé davantage d'individus de *B. invadens* dans les vergers mixtes probablement à cause du régime polyphage de cette espèce. Cette nouvelle espèce invasive, *B. invadens*, peut se développer au niveau de nombreuses autres espèces fruitières autres que le manguier, ce qui lui permet d'accroître ses potentialités de reproduction. **Conclusion**. Une lutte efficace contre cette espèce invasive requiert (i) l'approfondissement de recherches fondamentales et une recherche appliquée efficace, (ii) un paquet technologique efficace en lutte intégrée, (iii) une lutte menée à l'échelle du bassin de production, (iv) un effort général mené à la fois par les centres nationaux de recherche, les services du développement, les exportateurs, les associations de planteurs et les différents intervenants au niveau des filières fruitières (principalement mangue).

Sénégal / *Mangifera indica* / Tephritidae / *Ceratitis* / *Dacus* / *Bactrocera cucurbitae* / *Bactrocera invadens* / biodiversité / piège / appât pour piégeage

1. Introduction

The West Africa region is an expanding export centre of tropical and subtropical fruit, despite capacity that is limited in comparison with Asian or Central and South American production; it has been growing significantly in the last ten years, especially in Senegal [1]. Senegalese production of mango, in particular, has increased twofold in 15 years to reach about 90,000 t in both 2005 [1] and 2006. By ripening at the end of the dry season and at the start of the rainy season, the mango is a fundamental source of nutrition for rural populations living in the Sudano-Sahelian regions of West Africa: it is rich in potassium, alpha-carotene, vitamin C and calcium. Mango exports also generate valuable income for Senegal, where mango exportations reached 6,410 t in 2006 [1] to lift Senegal into second place among West African countries exporting mangoes to Europe. However, reliable export markets for mangoes can be guaranteed only when a country is able to produce high-quality fruits, free from disease and insects, especially quarantine pests.

In this context, mango quality in Senegal is hampered not only by socio-economic constraints but also by three kinds of phytosanitary problems: (i) phytopathological (anthracnosis, stem-end rot, *Oidium* and other pathogens), (ii) physiological disorders (jelly seed, soft nose), and (iii) insects. If these phytosanitary problems are controlled, Senegal could become the leading exporter of mango in West Africa. The most destructive of the many harmful insect species are thrips (Thysanoptera) on flowers; mealy bugs (Hemiptera: Pseudococcidae), mainly on leaves; termites (Isoptera: Termitidae) attacking the roots, collar and trunk of live mango trees; and various fruit fly (Diptera: Tephritidae) species in fruits. Our study focused on this last pest group.

A brief review of the extent of fruit fly research in Senegal shows very little has been done to investigate fruit flies, to assess either their prevalence or the losses they cause in Senegal's main horticultural crops. The earliest record is the mission report from a century ago of an Italian entomologist, F. Silvestri, who was looking for natural parasitoids of medfly in Senegal. Silvestri mentioned the presence of *Ceratitis silvestrii* Bezzi on the fruits of the shea-butter tree [2]. The record of *Ceratitis giffardi* Bezzi in the same publication probably refers to *Ceratitis cosyra* (Walker) [3]. De Meyer listed a specimen that is conspecific with other *C. cosyra* material and that originates from Senegal from this period. *Ceratitis bremii*, described by Guérin-Méneville from Senegal in 1843, was checked by De Meyer [4]. *Ceratitis capitata* was also previously listed from Senegal [5] but without a precise first date. Other fruit fly records have covered *Dacini* fly species associated with cucurbit crops such as *Dacus ciliatus* Loew [6–8] and *Dacus* spp. [9, 10]. We recapitulated a preliminary list of fruit fly species from the Niayes area and their first records in Senegal (*table I*).

In fact, no real overview of the tephritid species has been reported for this country, especially on fruit crops (mangoes, citrus, etc.). Questions had been asked by a number of people prior to 2004 about the occurrence of many fruit fly species in Senegalese orchards. To get an up-to-date and complete view of the status of fruit fly species living in mango orchards in Senegal, Senegalese teams (CERES-LOCUSTOX and DPV) and PIP-COLEACP-CIRAD carried out an experiment during the 2004 season. It focused on the trapping of fruit flies with several attractants in different types of orchards near Dakar. The experiment that we thus carried out in six orchards in the Niayes region determined the fly species captured, monitored their population fluctuations before, during and after the mango season, and analysed the data.

2. Materials and methods

2.1. Study sites

The Niayes region in Senegal is characterised by a long sandy strip of 180 km length and 10–30 km width along the Atlantic coast from Thiès (south) to St-Louis (north). This zone is characterised by a Sahelian climate with unimodal rainfall (250–350 mm yearly) from July to September. It

Table I.
Preliminary list of fruit fly species collected from Senegal.

Subgenus	Genus	Species	Descriptor	Date of first citation	Locality of first citation
Pardalaspis	*Ceratitis*	*bremii*	Guérin-Méneville	1843	Casamance
Ceratalaspis	*Ceratitis*	*cosyra*	(Walker)	1912	Dakar
Ceratalaspis	*Ceratitis*	*silvestrii*	Bezzi	1913	Dakar
Ceratitis	*Ceratitis*	*capitata*	(Wiedemann)	Before 1992	Bayakh
Ceratalaspis	*Ceratitis*	*quinaria*	(Bezzi)	2004	Keur Moussa
Pterandrus	*Ceratitis*	*fasciventris*	(Bezzi)	2004	Keur Moussa
Pterandrus	*Ceratitis*	*anonae*	Graham	2004	Keur Moussa
Pterandrus	*Ceratitis*	*flexuosa*	(Walker)	2004	Keur Moussa
Pardalaspis	*Ceratitis*	*ditissima*	(Munro)	2004	Keur Moussa
Pardalaspis	*Ceratitis*	*punctata*	(Wiedemann)	2004	Keur Moussa
Zeugodacus	*Bactrocera*	*cucurbitae*	(Coquillett)	2003	Dakar
Bactrocera	*Bactrocera*	*invadens*	Drew Tsuruta & White	2005	Keur Moussa
Dacus	*Dacus*	*bivittatus*	(Bigot)	1984	No specified locality given
Dacus	*Dacus*	*guineensis*	Hering	2004	Keur Moussa
Didacus	*Dacus*	*ciliatus*	Loew	1984	Many
Didacus	*Dacus*	*vertebratus*	Bezzi	1984	Camberene
Didacus	*Dacus*	*elutissimus*	Bezzi	2006	Djourbel
Leptoxyda	*Dacus*	*longistylus*	Wiedemann	1835	No specified locality given
Leptoxyda	*Dacus*	*xanthinus*	White & Goodger	2009	Keur Moussa
Leptoxyda	*Dacus*	*pleuralis*	Collart	2006	No specified locality given
Lophodacus	*Dacus*	*velutifrons*	White & Goodger	2009	Keur Moussa
Lophodacus	*Dacus*	*senegalensis*	White & Goodger	2009	Richard Toll
Psilodacus	*Dacus*	*annulatus*	Becker	2006	Tiougoune

is composed of sandy soils cut across by interdune depressions with high agronomic potential. It is both the premier economic region of Senegal, with well-developed peri-urban farming, and the principal fruit-producing area, with many orchards of mangoes and citrus. During the last ten years, it has been the first mango export region, providing 80% of all the country's mango exports. Grafted cultivars predominate because growers were quick to appreciate the comparative advantage of this product for export to Europe.

For our experiment, trapping activities were conducted in the southern zone of Niayes. A total of six sites (*table II*) was selected in (i) Keur Moussa, (ii) Keur Sega, (iii) Notto Gouyé Diama A, (iv) Mbambilor, (v) Keur Ndame Lô, and (vi) Notto Gouyé Diama B. The first three sites were mixed mango orchards, with Kent and Keitt mango trees predominant, and the three other sites were homogeneous Kent mango orchards.

2.2. Trapping

Detection trapping was monitored during 20 consecutive weeks from June to October 2004, the experiment being carried out before, during and after the rainy season. In the Niayes region, the mango fruiting season begins in July and culminates in September, so the trapping period covered this targeted fruiting period.

The same type of device was used for each orchard – nine Tephri traps (from Sorygar SL, Spain), of which three contained

Table II.
Characteristics of the sites which were surveyed regarding the presence of fruit fly species (Diptera, Tephritidae) in mango orchards in the Niayes region, Senegal, in 2004.

Location	GPS coordinates	Orchard type Main cultivars	Description of the site	Fruits cultivated (common name and scientific name)	Neighbouring crops
Keur Moussa	Lat. 14° 46' 32" N; long. 17° 08' 22" E	Mixed mango orchard: Kent, Keitt, Haden, etc.	12 ha planted with many fruit species such as citrus and mango, and with few vegetable crops. Large diversity of fruit tree species for demonstration. Mango trees > 15 years old productivity: good	Mango, *Mangifera indica* L.; Sweet orange, *Citrus sinensis* (L.) Osbeck.; Tangerine, *Citrus reticulata* Blanco; Grapefruit, *Citrus paradisi* Macfad.; Papaya, *Carica papaya* L.; Guava, *Psidium guajava* L.; African star apple, *Chrysophyllum albidum* G. Don; Soursop, *Annona muricata* L.; Cashew, *Anacardium occidentale* L.; Passion fruit, *Passiflora edulis* Sims.	**Cucurbitaceae**: *Cucurbita pepo* L., *Cucumis melo* L., *Citrullus lanatus* (Thunb.) Mats.
Keur Sega	Lat. 14° 48' 01" N; long. 17° 08' 22" E	Mixed mango orchard: Keitt, Kent.	80 ha, commercial farm planted mainly with mango and secondary vegetables. Mango trees: 10 to 12 years old productivity: good	Mango, *Mangifera indica* L.; Sweet orange, *Citrus sinensis* (L.) Osbeck; Lemon, *Citrus limon* (L.); Tangerine, *Citrus reticulata* Blanco; Grapefruit, *Citrus paradisi* Macfad.	**Cucurbitaceae:** *Cucumis melo* L., *Citrullus lanatus* (Thunb.) Mats. **Solanaceae:** *Solanum melongena* L.
Notto Gouyé Diama (A)	Lat. 14° 58' 17" N; long. 17° 00' 09" E	Mixed mango orchard: Kent, Keitt.	90 ha, commercial farm with mango (50%) and citrus (50%). Mango trees > 12 years old productivity: medium	Mango, *Mangifera indica* L.; Sweet orange, *Citrus sinensis* (L.) Osbeck; Lemon, *Citrus limon* (L.); Tangerine; *Citrus reticulata* Blanco; Grapefruit, *Citrus paradisi* Macfad.	**Cucurbitaceae:** *Cucurbita pepo* L.
Mbambilor	Lat. 14° 48' 08" N; long. 17° 11' 03" E	Homogeneous Kent mango orchard.	6 ha, small pure mango orchard. Mango trees: 6 years old productivity: low	Mango, *Mangifera indica* L.	Mango
Ndame Lo	Lat. 14° 51' 17" N; long. 17° 05' 40" E	Homogeneous Kent mango orchard.	10 ha of pure mango orchasd Mango trees: 7 to 8 years old productivity: good	Mango, *Mangifera indica* L.	Mango
Notto Gouyé Diama (B)	Lat. 14° 58' 29" N; long. 17° 01' 08" E	Homogeneous Kent mango orchard.	4 ha of pure mango surrounded by small mango orchard. Mango trees: 6 to 7 years old productivity: good	Mango, *Mangifera indica* L.	**Cucurbitaceae:** *Cucurbita pepo* L., *Citrullus lanatus* (Thunb.) Mats.

Terpinyl acetate (Ter) and three contained Trimedlure (Tri), both substances being diffused from solid cylindrical substrates or plugs (from IPS Ltd., England). The final three traps were baited with Torula yeast (Tor) using three tablets (from Chemtica Int., Costa Rica) in 300 mL of water per trap. In most orchards, the traps were placed in a "Latin square" distribution. Traps were suspended in the mango trees on branches in the lower third of the foliage, where they could be reached by hand. In order to prevent any potential weaver ant activity, the wire holding the trap was coated with thick grease. However, the density of weaver ants was quite low in this region.

Traps were serviced once a week. In each trap, the captured flies were counted, removed with tweezers and preserved in small vials containing alcohol (70°) once a week. Vials were labelled and transported to the laboratory. Parapheromone lures and insecticide cubes were changed at the end of every fourth week. The protein bait was replaced once a week after carefully cleaning the different traps.

2.3. Identification

By December 2004, the preserved fly species were identified by using De Meyer's articles [3, 4, 11, 12] and the White and Elson-Harris book [5].

Some undetermined Dacinae specimens were sent to Ian White (BNHM-London, UK) for identification, while some specimens of Ceratitinae fly were also sent to Marc De Meyer (RMCA, Tervuren, Belgium).

2.4. Statistical analysis

All statistical analyses were conducted with SAS software [13]. The linear mixed-effects model analysis of variance (ANOVA) procedure, PROC MIXED, was used. The mixed model analysis is well able to adjust for the serial auto-correlation among repeated samples on each experimental unit over the weeks and months of data collection, as well as being able to evaluate appropriately the variance-covariance test structure of several sources of random error terms involved [14]. We considered the "orchard type" and "attractant" as the fixed effects factors, and "locality" (nested) within orchard type, sample months and sample weeks (nested) within months as the random effects factors. Again, counts of trapped insects were $\log10_{(x+1)}$-transformed before analysis to stabilise the variance. The ANOVA was followed by pairwise *t*-testing to compare the means of the two orchard types and the means of the three attractant baits. We also examined the nature of the interaction between orchards and attractants wherever it was significant. The analysis was done for each insect species greater than 100 in numbers trapped, since the attractants and insect abundance seem to be insect-specific.

The individual sample trap counts of the insect species (for species' overall total counts greater than 1000) were analysed by the Shannon-Weaver diversity index (H'). Jain *et al*. [15] gave H' as:

$$H' = \sum_{i=1}^{k} Pi \, \log e \; Pi$$, where k is the number of classification classes of insect abundance and P_i is the proportion of the total number of entries (or cell count, N) in the class. H' was estimated for each insect species by locality. There were six localities used in all and they fall into the two orchard types: mixed and homogeneous. Each value of H' was standardised by dividing it, by its maximum value ($\log_e k$), in order to keep the values in the range of 0–1 [16]. A one-way analysis of variance of the non-transformed H' was performed for each locality using all classifying insect types.

The Shannon diversity index has been used to determine the evolution and distribution pattern in several insect groups in relation to trapping [17] and also in Tephritidae biodiversity [18].

Furthermore, hierarchical cluster analysis of the diversity indices obtained for the localities sampled was used to assess the level of intra-orchard type similarities based on the various insect species trapped. This was done using the cluster procedure of SAS.

3. Results

3.1. Preliminary inventory

At this step, a total of 18 species was determined.

The fruit fly species captured in the traps from the different orchards (*table III*) were: *Ceratitis cosyra* (Walker), *C. silvestrii* Bezzi, *C. quinaria* (Bezzi), *C. fasciventris* (Bezzi), *C. capitata* (Wiedemann), *C. ditissima* (Munro), *C. anonae* Graham, *C. bremii* Guérin-Méneville, *C. punctata* (Wiedemann), *C. flexuosa* (Walker), *Dacus ciliatus* Loew, *D. vertebratus* Bezzi, *D. bivittatus* (Bigot), *D. guineensis* Hering, *D. xanthinus* White & Goodger, *D. velutifrons* White & Goodger, *Bactrocera cucurbitae* (Coquillett) and *B. invadens* Drew Tsuruta & White.

Ceratitis cosyra, *C. silvestrii*, *C. fasciventris*, *C. capitata*, *C. ditissima*, *C. anonae*, *D. ciliatus* and *B. invadens* were captured in all six orchards. *Bactrocera cucurbitae* and *C. quinaria* were mainly captured in Keur Moussa, Keur Sega and Notto Gouyé Diama A. Other species such as *C. bremii*, *C. punctata*, *D. vertebratus*, *D. bivittatus*, *D. guineensis*, *D. xanthinus* and *D. velutifrons* were mainly captured in Keur Moussa, Keur Sega and Notto Gouyé Diama A, which are all mixed orchards, and a few specimens in homogeneous orchards (*table III*).

This study collected 11 fruit fly species, mainly in Keur Moussa, which had not previously been collected in Senegal, let alone the Niayes area (*table I*).

3.2. Lure response

For all insect species, the ANOVA results indicated a highly significant attractant effect of the lures used. However, the pattern of the attractants' mean differences depended on the insect (*table IV*). Three distinct patterns emerged: (a) very high insect counts by Ter, while Tor and Tri caught very low and nearly equal numbers of *C. cosyra*, *C. quinaria* and *C. silvestrii*; (b) very high insect counts by Tor, while Ter and Tri caught very low and equal numbers of *B. invadens*, *B. cucurbitae* and *D. ciliatus*; (c) very high insect counts by Tri, while Tor and Ter caught very low and nearly equal numbers of *C. fasciventris*, *C. anonae* and *C. capitata*.

The attractant Terpinyl acetate (Ter) was a significantly better attractant for *C. cosyra* ($F_{1.330}$ = 484.13, $P < 0.001$), for *C. quinaria* ($F_{1.326}$ = 17.43, $P < 0.001$), and for *C. silvestrii* ($F_{1.329}$ = 924.06, $P < 0.001$). It is a relevant attractant for these three fly species.

The attractant Trimedlure (Tri) was a significantly better attractant for *C. fasciventris* ($F_{1.329}$ = 66.78, $P < 0.001$), for *C. anonae* ($F_{1.329}$ = 31.18, $P < 0.001$), and for *C. capitata* ($F_{1.328}$ = 57.03, $P < 0.001$). It is a relevant attractant for these three fly species.

The attractant Torula pellets (Tor) was a significantly better attractant for *B. invadens* ($F_{1.328}$ = 91.45, $P < 0.001$), for *B. cucurbitae* ($F_{1.329}$ = 12.29, $P < 0.001$), and for *D. ciliatus* ($F_{1.329}$ = 31.54, $P < 0001$). They are suitable for attracting all the fly species present in or around orchards.

3.3. The abundance of different fruit fly species for each type of orchard

Overall, the abundance of insect species for mixed and homogeneous orchards was 59.1% and 41.9%, respectively, where these percentages refer to the total catch. The percentage ratio [mixed : homogeneous] varied from [53 : 47] for *C. cosyra* to [99 : 1] for *B. cucurbitae*, indicating quite high species counts caught in mixed orchards rather than in homogeneous orchards. Analysis of variance of the abundance revealed a significance difference between mixed and homogeneous orchards' overall species counts ($F_{1.3210}$ = 31.42, $P < 0.001$), but there were no significant differences between localities (within orchard types) ($F_{4.3210}$ = 0.60, P = 0.66).

The study of abundance of each fruit fly species in the two types of orchards (mixed or homogeneous) shows that the total of individuals of the different fruit fly species is generally higher for mixed mango orchards than for homogeneous mango orchards. Furthermore, some fly species,

Table III.
Types of orchards, sites and number of fruit fly individuals identified during a survey in mango orchards in the Niayes region, Senegal, in 2004.

Fruit fly species		Mixed orchards				Homogeneous orchards				Total of two types of orchards
		Keur Moussa	Keur Sega	Notto Gouyé Diama A	Total of individuals	Mbambilor	Keur Ndame Lô	Notto Gouyé Diama B	Total of individuals	
Ceratitis	*cosyra*	3212	7278	15420	25910	3405	2786	15658	21849	47759
	silvestrii	1248	4505	8836	14589	2896	4335	1088	8319	22908
	capitata	2853	282	143	3278	33	16	31	80	3358
	anonae	453	218	182	853	17	111	21	149	1002
	fasciventris	103	147	156	406	34	131	37	202	608
	quinaria	32	25	39	96	0	0	6	6	102
	ditissima	26	10	51	87	1	2	4	7	94
	punctata	0	5	10	15	0	0	0	0	15
	flexuosa	6	2	3	11	0	0	0	0	11
	bremii	4	1	2	7	0	0	0	0	7
Total of *Ceratitis*		7937	12473	24842	45252	6386	7381	16845	30612	75864
Bactrocera	*cucurbitae*	207	29	6	242	1	0	0	1	243
	invadens	705	236	137	1078	36	42	101	179	1257
Total of *Bactrocera*		912	265	143	1320	37	42	101	180	1500
Dacus	*ciliatus*	51	58	13	122	6	58	61	125	247
	bivittatus	3	1	2	6	0	1	2	3	9
	vertebratus	3	2	1	6	0	0	2	2	8
	guineensis	2	1	2	5	0	1	1	2	7
	xanthinus	1	0	2	3	0	0	0	0	3
	velutifrons	2	1	1	4	0	0	0	0	4
Total of *Dacus*		62	63	21	146	6	60	66	132	278

Table IV.
Results of an ANOVA studying interaction of fruit fly species (*C.*: *Ceratitis*; *B.*: *Bactrocera*; *D.*: *Dacus*) with attractants (Ter: Terpinyl, Tor: Torula, Tri: Trimedlure) (Niayes region, Senegal, in 2004).

Number of catches	Insect sp.	Orchard type	Attractant	Orchard × attractant interaction	Total count
> 100					
	C. cosyra	ns	Ter = +++	+++	47759
	C. silvestrii	ns	Ter = +++	+	22908
	C. quinaria	ns	Ter = +++	++	102
	B. invadens	+ (mixed)	Tor = +++	+++	1257
	D. ciliatus	ns	Tor = +++	ns	247
	B. cucurbitae	ns	Tor = +++	+++	243
	C. capitata	ns	Tri = +++	+++	3358
	C. anonae	+ (mixed)	Tri = +++	++	1002
	C. fasciventris	ns	Tri = +++	++	608
< 100					
	C. ditissima	–	Tor / –	–	94
	C. punctata	–	Tor / –	–	15
	C. flexuosa	–	Tor / –	–	11
	D. bivittatus	–	Tor / –	–	9
	D. vertebratus	–	Tor / –	–	8
	C. bremii	–	Tor / –	–	7
	D. guineensis	–	Tor / –	–	7
	D. velutifrons	–	Tor / –	–	4
	D. xanthinus	–	Tor / –	–	3

ns = not significant at the 5% level,
+ = significant at the 5% level,
++ = significant at the 1% level,
+++ = significant at the 0.1% level,
– = not analysed.

such as *C. flexuosa*, *C. punctata* and *C. bremii*, are only present in mixed mango orchards (*figure 1*).

3.4. Results of fly catches per orchard

The results of analysis of variance (ANOVA) showed a slightly significant difference between the two orchard types for *B. invadens* and *C. anonae* (*table IV*). Other insect species showed non-significant difference between the orchard types.

We observed that there was very highly significant orchard and attractant interaction with *B. invadens*, *B. cucurbitae*, *C. cosyra* and *C. capitata*. That was because mixed orchards had higher numbers of insect catches than homogeneous orchards. The above pattern of attractant catches remained the same for the mixed orchards, but the levels of catches by attractants were often about the same in homogeneous orchards.

3.5. Fluctuations of fly populations

We have illustrated the fluctuations of tephritid populations in the two types of orchards (*figures 2, 3*) because each category of orchard showed the same fly dynamics population patterns.

In the mixed mango orchard of Keur Moussa (*figure 2*), the three main fly pests during the dry season and the first rains

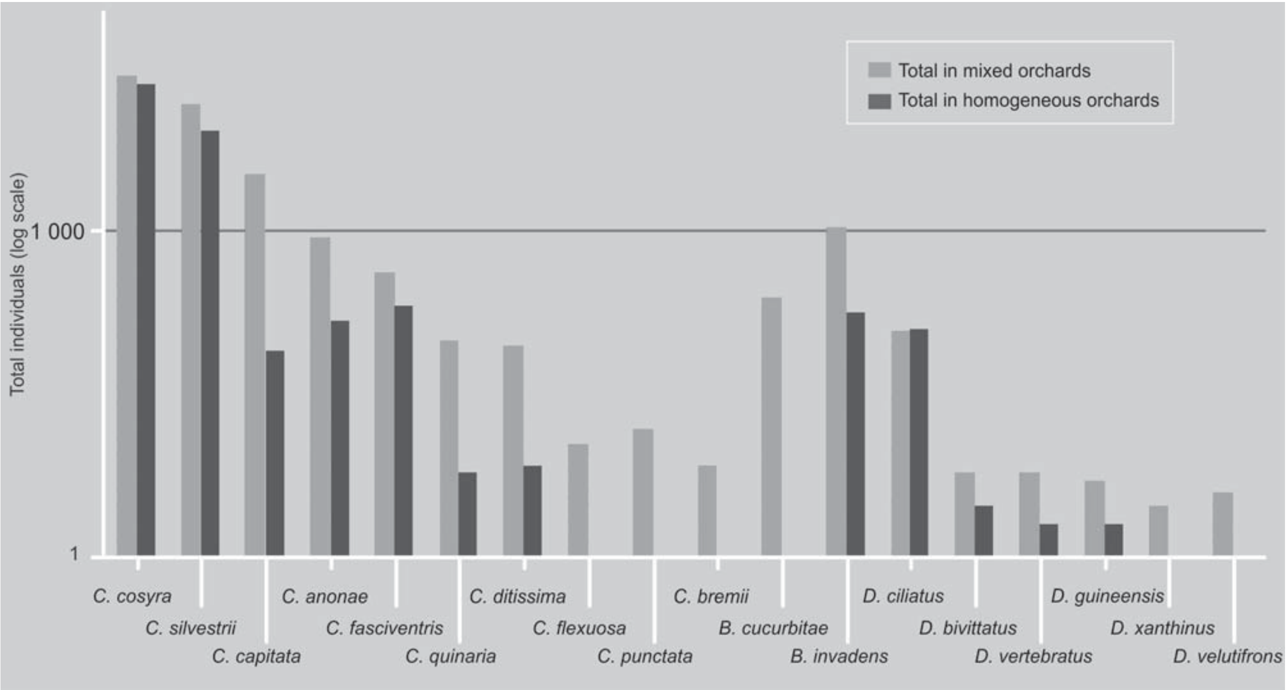

Figure 1.
Abundance of different fruit fly species according to two types (mixed or homogeneous) of mango orchard (Niayes region, Senegal, in 2004).

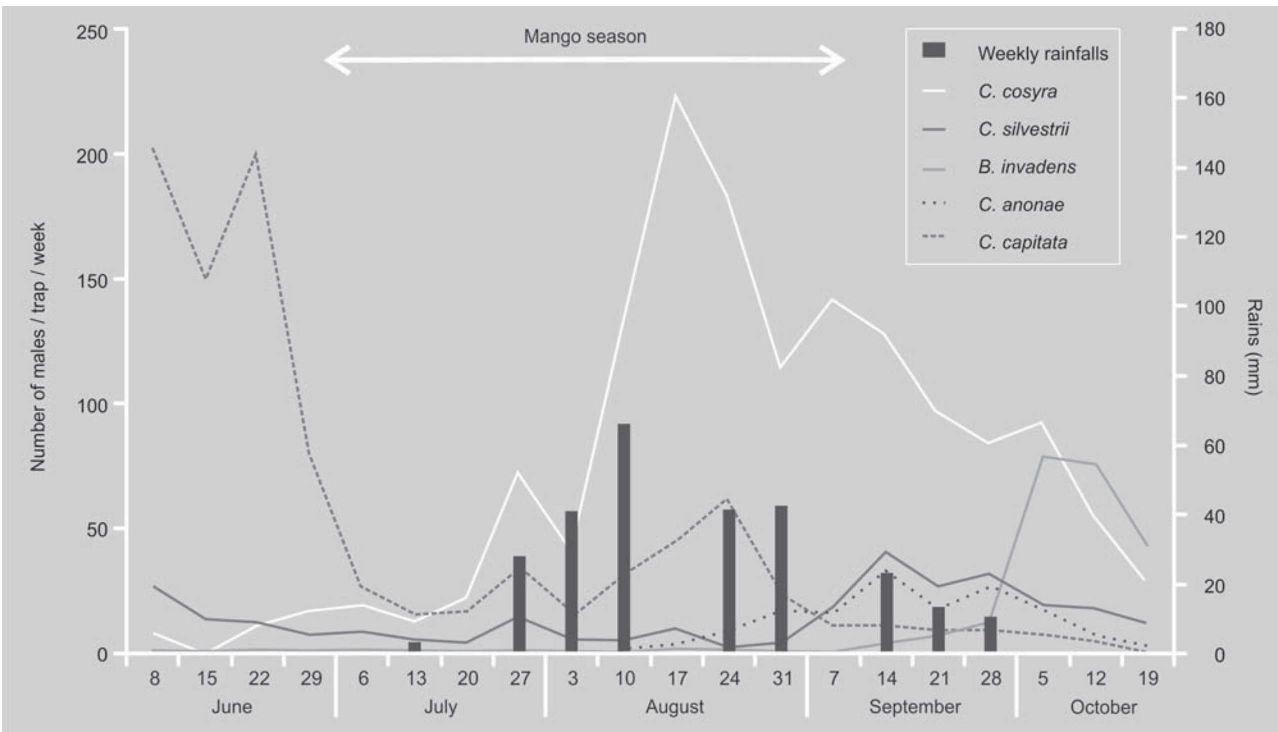

Figure 2.
Fluctuation in fruit fly populations in a mixed mango orchard (Keur Moussa, Niayes region, Senegal) from June to October 2004.

were *C. capitata*, *C. cosyra,* and *C. silvestrii* at a lower level. These species peaked in June for *C. capitata* with 200 flies per trap per week, in mid-August in 2004 for *C. cosyra* with 225 flies per trap per week and *C. silvestrii* with 60 flies per trap per week. After the rains, *B. invadens* peaked at the beginning of October with 80 flies per trap per week.

In the homogeneous mango orchard of Keur Ndame Lo (*figure 3*), the two main fly pests during the dry season and the first rains were *C. cosyra* and *C. silvestrii*. *Ceratitis cosyra* peaked at the beginning of August in 2004 with 220 flies per trap per week, and *C. silvestrii* with 220 flies per trap per week in mid-August. After the rains, the most significant fly pest was *B. invadens*, which peaked in mid-October with 20 flies per trap per week.

3.6. Biodiversity: estimates and analysis of diversity

The Shannon-Weaver diversity index was estimated for insect species by localities with only the food-bait Torula pellets (Tor) (*table V*).

The mean of the Shannon diversity index pooled over insect species within localities varied from 0.15 in Notto Gouyé Diama B (homogeneous mango orchard) to 0.81 in Keur Sega (mixed mango orchard) (*table V*). There were significant differences in diversity indices for two mixed orchards (Keur Sega and Notto Gouyé Diama A) at the $\alpha = 0.05$ significance level (*table V*), confirming the distribution of insect diversity was higher for the mixed orchards.

4. Discussion

4.1. Fruit fly inventory

This is a preliminary inventory of fruit fly species in the Niayes region of Senegal. An inventory of fruit flies of the Casamance area could also be useful in creating the first list of Senegalese fruit fly species. As we know, several important fly species were

Figure 3.
Fluctuation in fruit fly populations in a homogeneous mango orchard (Ndame Lo, Niayes region, Senegal) from June to October 2004.

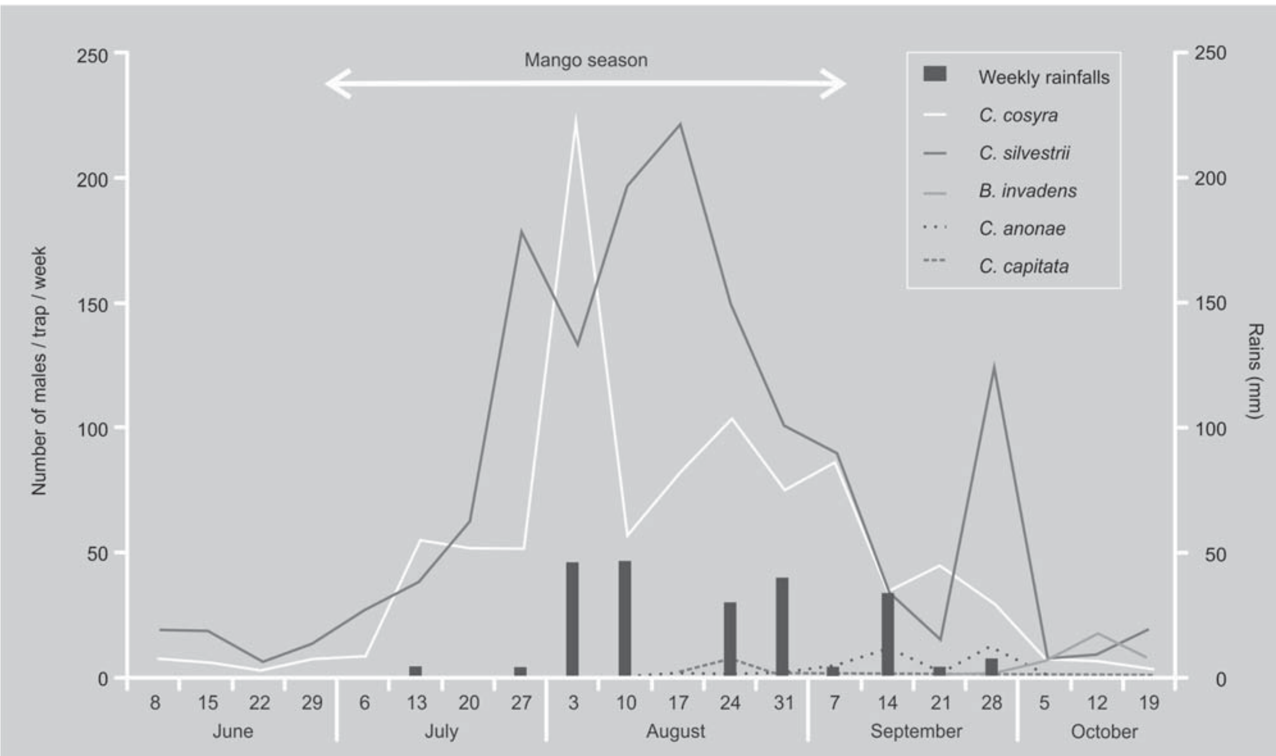

Table V.
Estimates of the Shannon-Weaver diversity index of six major insect species (with attractant = Torula) by localities (*C.*: *Ceratitis*; *B.*: *Bactrocera*; *D.*: *Dacus*) (Niayes region, Senegal, in 2004).

Locality	Orchard type	*B. invadens*	*C. anonae*	*C. capitata*	*C. cosyra*	*C. fasciventris*	*C. silvestrii*	Mean (± SE)[1]
Keur Séga	Mixed	0.95	0.78	0.86	0.97	0.56	0.75	0.81 (0.06) a
Notto G Diama A		0.99	0.51	0.59	0.91	0.59	0.73	0.72 (0.08) a
Keur Moussa		0.97	0.46	0.00	0.00	0.46	0.00	0.31 (0.16) b
Ndame Lo	Homogeneous	0.86	0.18	0.30	0.30	0.46	0.30	0.40 (0.10) b
Mbambilor		0.56	0.18	0.47	0.00	0.30	0.18	0.28 (0.08) b
Notto G Diama B		0.89	0.00	0.00	0.00	0.00	0.00	0.15 (0.15) b

SE: standard error.

[1] SNK tests in ANOVA at the 0.05 significant level.

previously recorded in Senegal such as *C. silvestrii* [2], *C. cosyra* under the name *C. giffardi* [3], *C. capitata*, *D. ciliatus* [6–8] and other *Dacus* species [9]. But other fruit flies, including *C. fasciventris*, *C. anonae* and the new invasive *B. invadens*, had not been recorded before this experiment. Since 2004, several studies have been carried out in Senegal [19, 20], focusing on the economic importance of the new invasive fruit fly species, *B. invadens*, and attempting for the first time to target control against it.

This latest invasive species, which originates from Southern Asia, was described in 2005 and called *Bactrocera invadens* Drew Tsuruta & White. It belongs to the *Bactrocera dorsalis* complex of tropical fruit flies which includes around 75 species often endemic to South East Asia [21–23]. From the general overview obtained, it seems that this new invasive species was still acclimatising in Senegal in 2004, although it is widely distributed in other parts of sub-Saharan Africa. This invasive species was found for the first time in Africa, in Kenya, in 2003 [24], then in Tanzania [25], and it was reported in 2004 in Sudan [26], Senegal [27] and Benin [28], as well as in other West African countries in 2005 [29]. However, both the timing and precise pathway of the invasion by *B. invadens* into Africa, especially West Africa, are not really known.

De Meyer has presented two relevant models which yielded similar estimates and largely corresponded to Equatorial climate classes with high levels of precipitation, suggesting that *B. invadens* prefers hot and humid environments [30]. Despite these preferences, we have seen that this invasive species can occur in dry savannah in West Africa and even in Sahelian areas such as Niayes. This can probably be explained by the existence of an anthropogenic microclimate with very well-developed peri-urban farming with many intensive irrigated horticultural crops in the Niayes zone. During the rainy season, this species is also widespread and abundant along the river Senegal from St-Louis to Kaedi (above 16 degrees of latitude) and Maghama, reaching Selibaby in Mauritania [29]. Present in Central Africa (Angola, Cameroon, Gabon, democratic Republic of Congo, etc.), *B. invadens* is still expanding in Mozambique, Zambia and Namibia[1]. This fly species has quickly become a tremendous threat on a continental scale.

Another invasive *Bactrocera* species found in Senegal is *B. cucurbitae*. The first collection of the melon fly in Senegal was carried out on November 5, 2003 [31] with collections of infested *Momordica charantia* around Dakar; the preliminary data from which was therefore checked in the following year.

Of other species belonging to the genus *Dacus* [32], two new *Dacus* species – *D. xanthinus* White & Goodger and

[1] De Meyer M., Mohamed S., White I., Invasive fruit fly pests in Africa, 2007, http://www.africamuseum.be/fruitfly/afroAsia.htm

D. velutifrons White & Goodger [10] captured with Torula yeast attractant in Tephri traps – can be highlighted. Hosts for Senegalese *Dacus* appear to belong to three plant families, namely Cucurbitaceae, Passifloraceae and Apocynaceae. The phylogenetic relationship between species groups or subgenera recognised within the genus *Dacus* and host utilisation was recently studied [33]. The dominant representatives of the genus *Dacus* are cucurbit feeders. However, the ancestral host family for African *Dacus* is still uncertain.

4.2. Major and minor pest species

In Senegal, we found roughly the same fly inventory (taken in mango orchards) as in the Sudanian zone *lato sensu* of Benin, except for a few *Dacus* species. Among the 18 species, only *B. invadens*, *C. cosyra*, *C. silvestrii* and *C. quinaria* are economically significant for mango production in Borgou [28] (Benin), with *B. invadens* as the number one pest [34] and *C. cosyra* as the number two.

Today, *Bactrocera invadens* is a quarantine pest; it is on the alert lists of European [35] and North American plant protection organisations. This species has been reported to cause significant losses in cultivated mango and citrus crops in Benin [34], Kenya [36] and Tanzania [37]. *Bactrocera invadens* is particularly polyphagous. It attacks over 40 different species of fleshy fruits in Benin. As in Benin, it is commonly found in Senegal [38] in the main cultivated fruits such as mango (*Mangifera indica*), guava (*Psidium guajava*), sweet orange (*Citrus sinensis*), mandarin (*Citrus reticulata*), tangelo (*Citrus reticulata* × *Citrus paradisi*), pomelo (*Citrus paradisi*), kumquat (*Fortunella margarita*), soursop (*Annona muricata*), papaya (*Carica papaya*), and wild species such as tropical almond (*Terminalia catappa*), *Sclerocarya birrea* and *Vitellaria paradoxa* in Benin [28, 29, 34, 39]. This fly is also found less frequently in Benin in cashew (*Anacardium occidentale*) [40], avocado (*Persea americana*), banana (*Musa acuminata*), malay apple (*Sizygium malaccense*), bully tree (*Manilkara zapota*), star apple (*Chrysophyllum albidum*), star fruit (*Averrhoa carambola*), chilli pepper (*Capsicum frutescens*), tomato (*Lycopersicum esculentum*) and wild custard apple (*Annona senegalensis*) [39]. As in other West African countries, the varying status of these host species can be evaluated differently in each of Benin's agro-ecological zones [39].

During recent years, the major pests of mango orchards in Senegal have been undeniably *C. cosyra* and *B. invadens* [1, 19, 20], while the major citrus pests are *C. capitata* and *B. invadens* (Rey, pers. commun.). According to Rey's observations and some collections we have carried out in Senegal, the major cucurbit pests remain *B. cucurbitae* and, to a lesser extent, *D. ciliatus*. Minor pests, including fruit fly species of no real economic importance such as *C. quinaria* and *C. fasciventris*, have been found in low numbers in Senegal in recent years [38].

The 2004 exercise was a snapshot in time and nobody could predict the later abundance of each species found. The most plausible hypothesis would be a significant decrease in the tephritid biodiversity in Senegalese orchards due to the arrival and the quick dispersal of *B. invadens* throughout the country. Any decrease would be similar in the north along the Senegal River where *B. invadens* is very abundant both during and after the rainy season.

These two Asian *Batrocera* invaders remain major horticultural pest species, widespread not just in Senegal, where *B. invadens* predominates on fruit crops [28] and *B. cucurbitae* on vegetable crops [31], but also in 14 other West African countries.

4.3. Lure response

Exactly the same pattern for lure response is found in Benin as in Senegal. Terpinyl acetate is a suitable attractant for *C. cosyra*, *C. quinaria* and *C. silvestrii* [34]. Trimedlure is a suitable attractant for *C. fasciventris*, *C. anonae* and *C. capitata* [28]. Torula yeast is a polyvalent attractant for all tephritid species, mainly the females, but also the juvenile males [34].

Methyl eugenol was not used in Senegal during the 2004 mango season because nobody anticipated the presence of any *Bactrocera* species to be attracted by the parapheromone methyl eugenol at that time. But Torula pellets worked quite well and the first adults of *B. invadens* were quickly captured after the first rains in mixed mango orchards (*figure 2*) as well as in homogeneous ones (*figure 3*). A few males and many females were caught in Torula-baited traps, which remain good attractants. In Benin, Torula bait works better than the dry '3-component' food bait tested during three consecutive years (Vayssières *et al.*, unpubl.) in Benin.

The protein bait Torula is an attractant that does not work in the same way as the parapheromones but instead as a food substance necessary for sexual maturation of adults and the development of eggs. So, food-baited traps are more general attractants than the specific attractant of a pheromone lure. Therefore, protein baits can indicate the presence of most fruit fly species living or just flying in a particular environment. For biodiversity studies, it is an excellent attractant.

4.4. Fluctuations of populations

The ratio of flies per trap per week shows that, overall, Senegal had a very moderate infestation of *C. cosyra* as they peaked at 200–220 flies per trap per week for both mixed and homogeneous mango orchards. The recorded infestation of this species was less than that in Benin during 2005–2006 [34].

For *B. invadens*, its very low flies per trap per week ratio in 2004 may mean that this new invasive species was in the 'arrival' and 'installation' phases in Senegal, and especially in the Niayes area. The very high peaks of *B. invadens* we have encountered in Senegal with recent detection trapping activities with the WAFFI [West African Fruit Fly Initiative, based at the International Institute of Tropical Agriculture (IITA) station of Cotonou-Benin] reveal high levels (more than 4000–5000 flies per trap per week), irrespective of the area in Niayes, Siné Saloun and the Casamance. Since 2005, they have been peaking dramatically in the middle or during the second half of the mango season.

4.5. Biodiversity

Keur Moussa was the most diverse site, with ten available host species (*table II*). The differing seasonalities of these different host species can provide food for tephritids over a long period. The situation is similar – but at a lower level – for Keur Sega (seven different hosts) and Notto Gouyé Diama A (six different hosts).

Mixed orchards with different fruit species (mangoes, citrus, guavas, etc.) generally had a greater abundance of different fruit fly species (*table II*) than homogeneous mango orchards. Furthermore, some fly species such as *B. cucurbitae*, *C. punctata*, *C. bremii* and *C. flexuosa* are not present in homogeneous mango orchards (*figure 1*).

Six years after our preliminary detection of these 18 fruit fly species, the percentage frequencies of these Senegalese fly species could be quite different. According to Rey, a decreasing biodiversity index in the Niayes area was noticed during the 2008 and 2009 seasons. The heavy colonisation of *B. invadens* in all agro-ecological zones of Senegal could be responsible for the displacement of native tephritid species in Senegal, just as we have already seen in Benin [28] with the same fly species, or in Reunion Island [41, 42] with *Bactrocera zonata* and other *Ceratitis* species.

5. Conclusion

This short survey conducted using fruit fly traps in Senegal's main fruit-producing area in 2004 was able to: (i) summarise the differences and the fly diversity observed between mango orchards and mixed orchards, and (ii) highlight the presence of the invasive species, *B. invadens*, for the first time in this area and thus in Senegal.

In terms of fluctuations in fruit fly populations, we have only a snapshot taken during these few months of the 2004 season. This snapshot is interesting because it depicts the beginning of the acclimation of *B. invadens* in Senegal. This alien species was prevalent in all six orchards studied but at low levels, due probably to its recent arrival in the region. It also shows that many tephritid species are present in Senegalese orchards within homogenous mango orchards, but especially within mixed orchards (mango-dominant). The three mixed mango orchards surveyed present the highest fruit fly diversity overall. The greater diversity of potential hosts could lead to higher diversity in fruit flies. For instance, Keur Moussa, with a dozen fleshy fruit species (*table II*), harbours the most abundant range of fly species as compared with those of Mbambilor or Ndame Lo, with fewer fruit species. This is an indication of the extent of host availability in the orchards rather than the fruit fly pest fauna. Thus, the greater the extent of host fruit species in the orchard, the greater the fruit fly diversity.

Despite the publication of several recent important articles on the host range of *B. invadens* in both East Africa [36, 37, 43] and West Africa [34, 39], much more knowledge is needed on its biology, ecology and behaviour. Particularly, studies are needed on its life history, its spread (adaptive significance of its movements in relation to environmental factors), its biotic and abiotic mortality factors, demographic analysis in function of different hosts and, finally, a modelling system in relation to control strategies. We need "to learn this fly" because this invasive fly species is out-competing and replacing the native fly species, as we have previously observed [28], and also noted in Kenya [44] and in Tanzania [45]. The interspecific competition of *B. invadens* and *C. cosyra* leads to a displacement of the native species in favour of the invasive one, a phenomenon frequently observed for fruit fly introductions and invasions, especially for the genus *Bactrocera* on other continents [46].

To control *B. invadens*, it is clear that the high comparative advantages (in terms of biology, ecology and behaviour) of this alien species *versus* native fly species necessitate a strong effort. The following four aims should be fulfilled:

(i) research effort is still needed for *B. invadens* even though we have some preliminary results on its life history,

(ii) an IPM package is required in order to reduce the fly population below an Economic Injury Level,

(iii) for several control methods to be effective, they should be planned as an area-wide approach,

(iv) the management of this alien species also requires a large sub-regional effort with joint contributions and synergies.

To this end, some very interesting initiatives are already being developed in Senegal through the DPV (*Direction de la Protection des Végétaux*) (with Kemo Badji) and through the FAES (*Fondation Agir pour l'Education et la Santé*) (with Christiaan Kooyman) focused on biological control activities in collaboration with WAFFI.

Acknowledgements

We would like to extend our thanks to the six growers in the Niayes area who gave us a warm welcome and their encouragement for the short study carried out in their orchards. This study was funded by the COLEACP-PIP (*Comité de Liaison Europe-Afrique-Caraïbes-Pacifique-Programme Initiative Pesticides*) and managed by the CERES (*Centre de Recherches en Eco-toxicologie pour le Sahel*), the DPV and CIRAD (*Centre de Coopération Internationale en Recherche Agronomique pour le Développement*). We are extremely grateful for all their confidence in our work. We also thank most sincerely Antonio Sinzogan, Appolinaire Adandonon and David Millar, who read this document and made a number of relevant remarks. Many thanks to Ian White [BNHM (British Natural History Museum), London, UK], Richard Drew [ICMPFF (International Centre for Management of Pest Fruit Flies), Australia] and Marc De Meyer [RMCA (Royal Museum for Central Africa), Belgium] for identification or confirmation of some tephritid species.

References

[1] Rey J.-Y., Dia M.L., Mangues : des vergers villageois aux nouvelles plantations d'exportation, in : Duteurtre G., Faye M.D., Dieye P.N. (sous la direction de), L'agriculture sénégalaise à l'épreuve du marché, ISRA-Karthala, Dakar, Sénégal, 2010, chapitre 12, 257–279.

[2] Silvestri F., Viaggio in Africa per cercare parassiti di mosche dei frutti, Boll. Lab. Zool. Gen. Agrar. R. Sc. Super. Agric., Portici, 8 (1913) 1–164.

[3] De Meyer M., Revision of the subgenus *Ceratitis* (Ceratalaspis) Hancock (Diptera Tephritidae), Bull. Entomol. Res. 88 (1998) 257–290.

[4] De Meyer M., Additional notes and records on the subgenus *Ceratitis* (*Pardalaspis*) Bezzi, 1918 (Diptera: Tephritidae), Bull. Ann. Soc. R. Belge 134 (1998) 199–202.

[5] White I.M., Elson-Harris M.M., Fruit flies of economic significance: their identification and bionomics, CAB Int., Wallingford, U.K., 1992, 601 p.

[6] Froissart R., Gerard M., Vaissière B.E., Integrated production of out of season cantaloupes in West Africa, Fruits 50 (1995) 359–374.

[7] Vaissière B.E., Froissard R., Pest management and pollination of cantaloupes grown under spunbonded row covers in West Africa, J. Hortic. Sci. 71 (1996) 755–766.

[8] Badji H., Coly E.V., Han S.H., Niang A.A., Control of fruit flies, *Didacus* spp. on cucurbits in Senegal (Diptera Tephritidae), Bull. Soc. Entomol. Fr. 106 (2001) 181–191.

[9] White I.M., Taxonomy of the Dacina (Diptera: Tephritidae) of Africa and the Middle East, Afr. Entomol. Mem. 2 (2006) 1–156.

[10] White I.M., Godger K.F.M., African *Dacus* (Diptera: Tephritidae); new species and data, with particular reference to the Tel Aviv univ. coll., Zootaxa 2127 (2009) 1–49.

[11] De Meyer M., Systematic revision of the subgenus *Ceratitis* MacLeay s.s. (Diptera: Tephritidae), Zool. J. Linn. Soc. 128 (2000) 439–467.

[12] De Meyer M., On the identity of the Natal fruit fly *Ceratitis rosa* Karsch (Diptera: Tephritidae), Bull. l'Inst. R. Sci. Nat. Belg., Entomol. 71 (2001) 55–62.

[13] Anon., The SAS System for Windows, Version 9.1, SAS Inst. Inc., Cary, N.C., U.S.A., 2003.

[14] Littell R.C., Milligen G.A., Stroup W.W., Wolfinger R.D., SAS system for mixed models, SAS Inst. Inc., Cary, N.C., U.S.A., 1996, 633 pp.

[15] Jain S.K., Qualset C.O., Bhatt G.M., Wu K.K., Geographical patterns of phenotypic diversity in a world collection of durum wheats, Crop Sci. 5 (1975) 700–704.

[16] Abdi A., Bekele E., Asfaw Z., Teshome A., Patterns of morphological variation of sorghum [*Sorghum bicolor* (L.) Moench] landraces in qualitative characters in North Shewa and South Welo, Ethiopia, Hereditas 137 (2002) 161–172.

[17] Wyatt Hoback W., Svatos T.M., Spomer S.M., Highley L.G., Trap color and placement affects estimates of insect family-level abundance and diversity in a Nebraska salt march, Entomol. Exp. Appl. 91 (2003) 393–402.

[18] Uchôa-Fernandes M.A., Oliveira I., Molina R.M.S., Zucchi R.A., Biodiversity of frugivorous flies (Diptera: Tephritoidea) captured in citrus groves, Mato Grosso do Sul. Neotrop. Entomol. 32 (2003) 239–246.

[19] Ndiaye M., Diop M., Dioh S., Niang M., Plan d'actions « Lutte contre les mouches des fruits », Rép. Sénégal, Minist. Agric. Hydraul. Rur. Séc. Alim. / USAID, Com. Lutte contre les mouches des fruits, Dakar, Sénégal, 2006, 18 pp.

[20] Ndiaye M., Dieng E.H.O., Delhove G., Population dynamics and on-farm fruit fly integrated pest management in mango orchards in the natural area of Niayes in Senegal, Pest Manag. Hortic. Ecosyst. 14 (2008) 1–8.

[21] Drew R.A.I., Hancock D.L., The *Bactrocera dorsalis* complex of fruit flies (Diptera: Tephritidae: Dacinae) in Asia, Bull. Entomol. Res. (Suppl. Ser.) 2 (1994) 1–68.

[22] Tsuruta K., White I.M., Eleven new species of the genus *Bactrocera* Macquart (Diptera: Tephritidae) from Sri Lanka, Entomol. Sci. 4 (2001) 69–87.

[23] Clarke A.R., Armstrong K.F., Carmichael A.E., Milne J.R., Raghu S., Roderick G.K., Yeates D.K., Invasive phytophagous pests arising through a recent tropical evolutionary radiation: the *Bactrocera dorsalis* complex of fruit flies, Annu. Rev. Entomol. 50 (2004), 293–319.

[24] Lux S.A., Ekesi S., Dimbi S., Mohamed S., Billah M., Mango-infesting fruit flies in Africa: Perspectives and limitations of biological approaches to their management, in: Neuenschwander P., Borgemeister C., Langewald J. (Eds.), Biological control in IPM systems in Africa, CABI Publ., 2003, Wallingford, U.K., pp. 277–294.

[25] Mwatawala M.W., White I.M., Maerere A.P., Senkendo F.J., De Meyer M., A new invasive *Bactrocera* species (Diptera: Tephritidae) in Tanzania, Afr. Entomol. 12 (2004) 154–156.

[26] Luckman G., A helping hand for Sudan, Bull. Aust. Quar. Insp. Serv. 05, Canberra, Australia, 2004, p. 4.

[27] Vayssières J.-F., Rapport de mission sur l'essai « Piégeage de Tephritidae du manguier » au Sénégal, du 11 au 20 décembre 2004, CIRAD / COLEACP-PIP, Rapp. Int., Montpellier, France, 2004, 15 p.

[28] Vayssières J.-F., Georgen G., Lokossou O., Dossa P., Akponon C., A new *Bactrocera* species in Benin among mango fruit fly (Diptera: Tephritidae) species, Fruits 60 (2005) 371–377.

[29] Vayssières J.-F., Sinzogan A., Adandonon A., The new invasive fruit fly species *Bactrocera invadens* Drew Tsuruta & White, Reg. Control Fruit Fly Proj. West Afr., IITA-CIRAD, Leaflet n° 2, Cotonou, Benin, Apr. 2008, 4 p.

[30] De Meyer M., Robertson M., Mansell M., Ekesi S., Tsuruta K., Mwaiko W., Vayssières J.-F., Peterson T., Ecological niche and potential geographical distribution of the new invasive fruit fly *Bactrocera invadens* (Diptera Tephritidae), Bull. Entomol. Res. 100 (2010) 35–48.

[31] Vayssières J.-F., Rey J.-Y., Traoré L., Distribution and host plants of *Bactrocera cucurbitae* in West and Central Africa, Fruits 62 (2007) 391–396.

[32] White I.M., Taxonomy of the Dacina (Diptera: Tephritidae) of Africa and the Middle East, Afr. Entomol. Mem. 2 (2006) 1–156.

[33] Virgilio M., De Meyer M., White I.M., Backeljau T., African *Dacus* (Diptera: Tephritidae): molecular data and host plant associations do not corroborate morphology based classifications, Mol. Phylogenet. Evol. 51 (2009) 531–539.

[34] Vayssières J.-F., Korie S., Ayegnon D., Correlation of fruit fly (Diptera: Tephritidae) infestation of major mango cultivars in Borgou (Benin) with abiotic and biotic factors and assessment of damage, Crop Prot. 28 (2009) 477–488.

[35] Anon., Pest risk analysis on *Bactrocera invadens*, Eur. Mediterr. Plant Prot. Org. (EPPO), Paris, France, 2010, 114 p.

[36] Rwomushana I., Ekesi S., Gordon I., Ogol C.K.P.O., Host plants and host plant preference studies for *Bactrocera invadens* (Diptera: Tephritidae) in Kenya, a new invasive fruit fly species in Africa, Ann. Entomol. Soc. Am. 101 (2008) 331–340.

[37] Mwatawala M., De Meyer M., Makundi R.H., Maerere A.P., Seasonality and host utilization of the invasive fruit fly, *Bactrocera invadens* (Dipt., Tephritidae) in central Tanzania, J. Appl. Entomol. 130 (2006) 530–537.

[38] Ndiayes O., Plantes-hôtes et facteurs déterminants sur les infestations dues à *Bactrocera invadens* et *Ceratitis cosyra* sur *Mangifera indica* dans la zone des Niayes et du plateau de Thiès, Univ. Thiès, Mém. DEA, Thiès, Sénégal, 2009, 67 p.

[39] Vayssières J.-F., Sinzogan A., Adandonon A., Range of cultivated and wild host plants of the main mango fruit fly species in Benin, Reg. Control Fruit Fly Proj. West Afr., IITA-CIRAD, Leaflet n° 8, Cotonou, Benin, Febr. 2009, 4 p.

[40] Vayssières J.-F., Korie S., Coulibaly T., Temple L., Boueyi S., The mango tree in northern Benin: cultivar inventory, yield assessment, early infested stages of mangos and economic loss due to the fruit fly (Diptera: Tephritidae), Fruits 63 (6) (2008) 335–348.

[41] Duyck P.-F., David P., Quilici S., A review of relationships between interspecific competition and invasions in fruit flies (Diptera: Tephritidae), Ecol. Entomol. 29 (2004) 511–520.

[42] Duyck P.-F., David P., Pavoine S., Quilici S., Can host-range allow niche differentiation of invasive polyphagous fruit flies (Diptera: Tephritidae) in La Réunion? Ecol. Entomol. 33 (2008) 439–452.

[43] Mwatawala M., De Meyer M., Makundi R.H., Maerere A.P., Biodiversity of fruit flies (Diptera: Tephritidae) in orchards in different agro-ecological zones of the Morogoro region, Tanzania, Fruits 61 (2006) 321–332.

[44] Ekesi S., Billah M.K., Nderitu P.W., Lux S.A., Rwomushana I., Evidence for competitive displacement of *Ceratitis cosyra* by the invasive fruit fly *Bactrocera invadens* (Diptera:

Tephritidae) on mango and mechanisms contributing to the displacement, J. Econ. Entomol. 102 (2009) 981–991.

[45] Mwatawala M.W., De Meyer M., Makundi R.H., Maerere A.P., An overview of *Bactrocera* (Diptera: Tephritidae) invasions and their speculated dominancy over native fruit fly species in Tanzania, J. Entomol. 6 (2009) 18–27.

[46] Duyck P.F., David P., Quilici S., A review of relationships between interspecific competition and invasions in fruit flies (Diptera: Tephritidae), Ecol. Entomol. 29 (2004) 511–520.

Inventario de las especies de mosca de la fruta en los vergeles de mangos de la zona de Niayes en Senegal, en 2004.

Resumen — **Introducción**. En Senegal, antes de 2004, se desconocía bastante la lista de las especies de mosca de la fruta inventariadas. Por esta razón el PIP-COLEACP y el CIRAD, en colaboración con el Cérès-DPV, comenzaron en 2004 a colocar trampas de detección de moscas de la fruta en seis vergeles de mango situados en Niayes. **Material y métodos**. En esta zona, seleccionamos tres vergeles mixtos (con predominio de mango) y tres vergeles de mango mono-específicos. En cada vergel se emplearon tres tipos de atrayentes para Tephritidae: acetato de *Terpinyl* (Ter), trimedlure (Tri), y tórula (Tor). Se recogieron las trampas semanalmente. **Resultados**. Capturamos 77 642 moscas de la fruta en más de 4 meses de instalación de trampas; entre las 18 especies de mosca identificadas, encontramos diez especies de *Ceratitis*, seis especies de *Dacus* y dos especies de *Bactrocera*. Dentro del género de *Bactrocera*, identificamos dos especies de plagas de gran importancia económica: confirmamos la presencia de *B. cucurbitae* en los cultivos de Cucurbitaceae y detectamos la presencia de *B. invadens* para los cultivos frutícolas. Las principales especies de mosca mediterránea de la fruta presentes fueron *Ceratitis cosyra* y *C. silvestrii*. **Discusión**. Capturamos más especies de la mosca de la fruta en vergeles mixtos de mango que en vergeles homogéneos. Del mismo modo, capturamos más individuos de *B. invadens* en vergeles mixtos, probablemente a causa del régimen polífago de dicha especie. Esta nueva especie invasiva, *B. invadens*, puede desarrollarse igual que otras muchas especies frutales que no sean el mango, lo que le permite aumentar sus potencialidades de reproducción. **Conclusión**. La lucha eficaz contra esta especie invasiva requiere (i) la puesta en marcha de actividades de investigación fundamentales con el objetivo de redefinir una investigación aplicada eficaz, (ii) un paquete tecnológico eficaz de lucha integrada, (iii) una lucha realizada a escala de la cuenca productora, (iv) un esfuerzo general realizado a la vez por los centros nacionales de investigación, los servicios de desarrollo, los exportadores, las asociaciones de plantadores y los diferentes actores a nivel de las filiares frutales (principalmente mango).

Senegal / *Mangifera indica* / Tephritidae / *Ceratitis* / *Dacus* /*Bactrocera cucurbitae* / *Bactrocera invadens* / biodiversidad / caza con trampa / cebo para trampas