Fruit Flies of Economic Importance: From Basic to Applied Knowledge
Proceedings of the 7th International Symposium on Fruit Flies of Economic Importance
10-15 September 2006, Salvador, Brazil
pp. 71-79

Development of Improved Attractants and Their Integration Into Fruit Fly Management Programmes

P Sookar, S Permalloo, M Alleck & SI Seewooruthun

Ministry of Agro Industry & Fisheries, Réduit, Republic of Mauritius ento@intnet.mu; moa-entomology@mail.gov.mu

ABSTRACT: Fruit flies are major constraint to fruit production in Mauritius. The peach fruit fly, *Bactrocera zonata* (Saunders), the natal fly, *Ceratitis rosa* (Karsch), the medfly, *C. capitata* (Wiedmann) are the main pests of fleshy fruits. Fruit fly trapping trials were conducted in backyards to find the most effective combination of attractant and lures for females. There were two separate trapping trials, carried out in two different localities during the period November 2004 to March 2005. In the first trial, the attractants in different combinations were tested in International Pheromone McPhail Trap (IPMT). The attractants were as follows: (i) three patches containing Ammonium Acetate (AA) + Trimethylamine (TMA) + Putrescine (PT); (ii) Two patches of AA ; (iii) two patches of AA + one patch of PT ; (iv) two patches of AA + one patch of TMA; (v) one patch of solbait ; (vi) torula tablets; (vii) protein hydrolysate and (viii) GF120. Water and Triton B were used as retention device in traps baited with the patches. In the first trial, all treatments were equally effective in the capture of either female *B. zonata* or female *C. capitata* with the exception of protein hydrolysate and GF120 which trapped fewer numbers of flies. In the second trapping trial, additional trap types and lure combinations were assessed. The three component lure (AA + PT + TMA with water/Triton as retention device in IPMT) and the trap baited with Waste Brewer's Yeast captured significantly more female flies followed by IPMT with AA + PT + TMA / Sticky insert and the Easy trap. In all trials, females accounted for more than 75% of the catches.

Key Words: Fruit fly, *Bactrocera zonata, Ceratitis rosa, C. capitata,* IPMT, attractants

INTRODUCTION

Fruit flies (Diptera: Tephritidae) cause large losses to fruits throughout the world, and are recognized today as major insect pests of the horticultural and vegetable industries. A growing international trade has further increased their significance (Allwood, 1997). Fruit fly problems in Mauritius date back to the beginning of this century (Orian and Moutia, 1960). Eight pest species of fruit flies are known in Mauritius: the peach fruit fly *Bactrocera zonata* (Saunders), the natal fly *Ceratitis rosa* (Karsch), the medfly *C. capitata* (Wiedmann), the melon fly, *B. cucurbitae* (Coquillett), the ber fly *Carpomya vesuviana* Costa, the tomato fruit fly *Neoceratitis cyanescens* (Bezzi), the Indian Ocean cucumber fly *Dacus demmerezi* (Bezzi) and the Ethiopian fruit fly *D. ciliatus* (Loew). Control efforts in the past have been focused on cover sprays of insecticides, biological control and the Sterile Insect Technique SIT (Hammes, 1980). More recently, control has been directed towards area-wide management which is more effective when an entire area is treated, instead of individual efforts where reinvasions from the neighbouring areas continuously occur. An area-wide control was thus proposed (Landell Mills, 1991). A National Fruit Fly Control Programme (NFFCP) based on this concept has been operational since 1994, initially with financial and technical assistance from the European Union, and subsequently through sole Mauritian Government funding as from 1999. Control actions are currently being carried out in major fruit growing areas. To ensure the effectiveness of the NFFCP, there is continual and intensive monitoring. Traps baited with parapheromones/Malathion and liquid proteins are maintained in urban/village areas, in farming communities, and along the roadways in host areas. The traps are serviced every two weeks.

The study of the foraging behaviour for food, water, mating and egg-laying has led to new methodologies for monitoring and controlling several important fruit flies (Prokopy and Roitberg, 1984). A variety of protein hydrolysates have been used for trapping both sexes of fruit flies. Ammonia appears to be the principal attractant originating

Author for correspondence.
P Sookar

from these food lures (Bateman and Morton, 1981; Morton and Bateman, 1981). Lopez *et al*. (1971) found that baits of 3 % hydrolysed torula yeast with 4 % borax premixed in water in invaginated glass traps proved 2-40 times as attractive as the standard (pellets of enzymatic cottonseed hydrolysate with borax) in water as a bait for *Anastrepha suspensa* (Loew). However, in large control applications, such traps may eliminate large numbers of beneficial or non-target insects if they are not selective. Furthermore, aqueous protein hydrolysate-baited traps are difficult to deploy and are not very specific for fruit flies (Katsoyannos, 1994).

Traps have been made more specific by making them in shapes which are of specific significance to the target insects. Specificity can also be increased by adding a specific odour (e.g. sex attractant and food odour) (Economopoulos, 1989). Usually, visual attractants have been combined with odour attractants such as proteins, ammonium salts, pheromones, or combinations of more than one. One of the first patented combinations was the Pherocon trap that combined yellow colour with food odours such as protein hydrolysate and ammonium acetate (Neilson *et al*., 1976). Trapping systems that include cylindrical plastic traps and a food-based synthetic attractant were developed that are highly attractive to the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) females (Heath *et al.,* 1995, 1996, 1997). The food-based synthetic lure, composed of ammonium acetate, putrescine, and trimethylamine lures (Biolure, Suterra LLC, Bend, OR), emits volatile chemicals that are part of the odour of protein baits and other natural materials attractive to fruit flies.

An international network research project for the development of a female attractant system for medfly trapping was subsequently operated under IAEA/FAO, as a five year Coordinated Research Programme (CRP), as from 1995. The CRP enabled the testing of ammonium acetate, putrescine and trimethylamine in different combinations and in different types of traps. Significant achievements were made in the development of a female detection system for the medfly. The three-component synthetic female food attractant was accepted as a means of assessing the effectiveness of SIT programme efforts. Another 5-year CRP complementary to the above focusing on the development of improved attractants and their integration into SIT fruit fly management programmes, was initiated in 2000. Trials were geared towards the genera *Anastrepha, Ceratitis* and *Bactrocera* which attack over 300 species of fruits and vegetables in tropical, subtropical and temperate climates in five continents. The objectives of the CRP were mainly to develop and compare female-based food attractants in different environments, to provide a standardized detection system among fruit fly pest species and regions, and to develop female targeted bait/kill stations.

This paper presents results of using different food-based attractants for trapping of three fruit fly species, *B. zonata, C. rosa* and *C. capitata* for the period November 2004 to March 2005. Trials were conducted according to a common protocol devised by the IAEA, and agreed by the different participating countries which are from Latin America, Europe, Africa and Indian Ocean.

MATERIALS AND METHODS

Traps and lures. Several types of traps were used with female-targeted attractants in the field tests. These included a McPhail-type trap, which was an International Pheromones McPhail trap (IPMT); an Easy-trap; a coloured sphere trap. There were two types of female-targeted attractants tested in these studies. Liquid protein baits were as follows: (1) aqueous solution of 2% protein hydrolysate (vol:vol) (Beauvilliers Aromatique, France) +

3% borax, (2) aqueous solution of 8% GF120 (vol:vol) + 3% borax, and (3) aqueous solution of 12.5% laboratory modified waste brewery yeast (vol:vol) + 3% borax.. The food-based synthetic lures used were Solbait, ammonium acetate (AA), putrescine (PT) and trimethylamine (TMA) patches.

Field Tests. The field trials were conducted at two sites: Pointe aux Sables (5-20 m ASL) and Beau Bassin (290-355 m ASL) during the period November 2004 to March 2005. The targeted fruit flies were *B. zonata, C. rosa* and *C. capitata* and the main hosts during the period of study were mango, Indian Almond, Loquat, and Peach. Trials were set on individual host trees located in backyard gardens as adequate orchards are not available for experimentation.

Table 1. Description of treatments in Experiment 1 at Pointe aux Sables (PS) and at Beau Bassin (BB)

Treatments (IPMT trap)	Insect retention device	Location of test
2AA + PT	300 ml water[a]	PS, BB
2AA	300 ml water[a]	PS, BB
Protein hydrolysate	300 ml liquid Protein hydrolysate/ borax bait	PS
2AA + TMA	300 ml water[a]	PS, BB
AA + TMA	300 ml water[a]	PS, BB
AA + TMA + PT	300 ml water[a]	PS, BB
GF120	300 ml liquid GF120/borax bait	PS, BB
Torula yeast	300 ml water	BB
Solbait patch	300 ml water[a]	BB

[a] 0.01% Triton B aqueous solution

In the trial at Beau Bassin, two new treatments were included: Torula yeast pellets (three pellets of 3 gms each in 300 ml of water in an IPMT trap and Solbait patch with water/Triton B as retention device. The treatment protein hydrolysate in IPMT was not included.

Experiment 2 was conducted at Beau Bassin and then repeated at Pointe aux Sables. Table 2 summarises the treatments.

Table 2. Description of treatments in Experiment 2

Trap type	Treatments	Insect retention device
IPMT trap	AA + TMA + PT	Sticky insert
IPMT trap	AA + TMA + PT	300 ml water[a]
Easy trap	AA + TMA + PT	Sticky insert
IPMT trap	Protein hydrolysate	300 ml liquid Protein hydrolysate/ borax bait
Coloured Sphere	AA + TMA + PT	Sticky insert
IPMT trap	Modified waste brewery yeast (WBY)	300 ml liquid WBY/borax bait

[a] 0.01% Triton B aqueous solution

Traps were hung on fruit trees, 1 – 2 metres above the ground, in the lower half of the south-eastern part of the tree canopy. At each site, traps were set in five replicates of seven traps. The distance between two traps varied between 25 to 50 m in each replicate. Traps were serviced twice a week and all tephritids captured were collected in 70% alcohol. Fruit flies were identified, sexed and recorded. After data collection, traps within a replicated were rotated sequentially. During weekly renewal, the old liquid baits of IPMT traps were collected in a plastic bucket to avoid interference with traps. Similarly, synthetic lures that were changed after four weeks were collected in a plastic bag. The traps were rinsed with water before the addition of fresh bait. The trials were run for eight weeks.

Statistical Analysis. The sum total capture of insects in a trap was calculated and numbers of insects per trap per day were used for subsequent analysis. Data were transformed to stabilise the variance before analysing by using log (x + 1). Differences in capture among the experimental traps were determined using analysis of variance (ANOVA). Significant

ANOVAs were followed by the Tukey test ($P = 0.05$). All analyses were done with SPSS version 11.

RESULTS

Experiment 1. The mean numbers of *B. zonata*, *C. capitata* and *C. rosa* captured during the experiments at Pointe aux Sables and Beau Bassin are presented in Table 3 and 4, respectively. In the first trial at Pointe aux Sables, all treatments were equally effective in the capture of either female *B. zonata* or female *C. capitata* with the exception of protein hydrolysate and GF120, which trapped fewer numbers of flies. As regards trap captures for female *C. capitata,* there was no significant difference among the treatments. In the trial at Beau Bassin, Solbait and GF120 trapped fewer female *B. zonata* flies as compared to the other baits. There were no significant differences in the trap captures of either *C. capitata* or *C. rosa*. The three component synthetic lure in IPMT was as effective as any combination of the two component lures or the single AA lure. In both trials, females accounted for 77-97% of the total captures for the different baits.

Experiment 2. In the trial at Beau Bassin, the three component lure (AA + PT + TMA with water/Triton as retention device in IPMT) and the bait waste brewer's yeast captured significantly more female flies followed by IPMT with AA + PT + TMA / sticky insert and the Easy trap (Table 5). A similar trend was obtained for the captures of *C. rosa*. There were no significant differences in the captures of *C. capitata*. In the second trial at Pointe aux Sables, IPMT (AA + PT + TMA) with water/Triton captured significantly more female *B. zonata* or female *C. capitata* as compared to the other treatments (Table 6). All baits were equally effective in capturing *C. rosa*. In comparison of the two retention devices in the same trap type in both experiments, capture with IPMT baited with the three component lure and water/Triton was higher than that with a sticky insert. Among all the traps, females accounted for over 78% of the total capture.

DISCUSSION & CONCLUSION

Insect trapping is essential for population studies or for use in insect pest control programmes. Estimation of population size, detection of newly introduced species and evaluation of population reproductive ability are necessary components for any control system (Economopoulos and Haniotakis, 1994). Traps baited with the three component food-based synthetic attractant showed remarkable performance in capturing female *C. capitata* in tests conducted in Guatemala (Heath *et al.,* 1997). Epsky *et al.* (1999) reported that the best female-targeted traps, and specifically the traps baited with the food-based synthetic attractants, out-captured the male-targeted traps in studies that were conducted in sites with the lowest populations of *C. capitata*.

The trapping data showed that the population of *B. zonata* was highest followed by *C. rosa* and *C. capitata* at both sites. The tested lures were all female specific. Similar results were obtained by Bakri *et al.* (1998) in an argan forest in Morocco, Heath *et al.* (1995) in an orange/coffee intercrop in Guatemala and Gazit *et al.* (1998) in citrus in Israel. Trapping results demonstrated that the IPMT trap baited with the three component synthetic lure provides a good female *B.* zonata, *C. capitata* and *C. rosa* selective trapping system. The food-based synthetic attractant does provide a viable alternative to liquid protein baits as shown by the captures of *B. zonata* in experiment 1 (Tables 3 and 4). IPMT with the 3 component lure and water/Triton

as retention device appeared to be the best trap for trapping females of the three fruit fly species.

The female selectivity of the synthetic attractant observed will be of considerable value when used with *B. zonata* single-sex release of males and will further increase efficacy of the SIT for *B. zonata* by removal of the feral females without removal of sterile males.

Table 3. Experiment 1: Mean (±SD) number of fruit flies per trap per day captured at Pointe aux Sables

Treatments (IP McPhail trap)	n	Mean ± SD insects / Trap / Day								
		B. zonata			*C. capitata*			*C. rosa*		
		Females	Males	Total	Females	Males	Total	Females	Males	Total
2AA + PT	5	0.069 ± 0.029 ab	0.020 ± 0.009	0.089 ± 0.036 ab	0.008 ± 0.014	0.006 ± 0.004 a	0.014 ± 0.017	0.027 ± 0.020abc	0.020 ± 0.014	0.047 ± 0.032abc
2AA	5	0.062 ± 0.024 ab	0.011 ± 0.008	0.073 ± 0.033 ab	0.001 ± 0.002	0.000 ± 0.000 b	0.001 ± 0.002	0.014 ± 0.012abc	0.000 ± 0.000	0.014 ± 0.012bc
Protein hydrolysate	5	0.009 ± 0.007 b	0.009 ± 0.008	0.017 ± 0.014 b	0.001 ± 0.002	0.000 ± 0.000 b	0.001 ± 0.002	0.010 ± 0.017bc	0.001 ± 0.002	0.011 ± 0.016bc
2AA + TMA	5	0.159 ± 0.069 a	0.024 ± 0.014	0.184 ± 0.076 a	0.005 ± 0.003	0.003 ± 0.003 ab	0.008 ± 0.006	0.052 ± 0.030ab	0.026 ± 0.031	0.078 ± 0.058ab
AA + TMA	5	0.147 ± 0.076 a	0.029 ± 0.021	0.176 ± 0.097 a	0.002 ± 0.003	0.001 ± 0.003 ab	0.004 ± 0.006	0.038 ± 0.027ab	0.010 ± 0.006	0.048 ± 0.032abc
AA + TMA + PT	5	0.131 ± 0.077 a	0.019 ± 0.021	0.151 ± 0.099 a	0.005 ± 0.007	0.001 ± 0.002 b	0.006 ± 0.009	0.059 ± 0.034a	0.027 ± 0.024	0.086 ± 0.058a
GF120	5	0.023 ± 0.016 b	0.001 ± 0.014	0.024 ± 0.017b	0.001 ± 0.002	0.000 ± 0.000 b	0.001 ± 0.002	0.005 ± 0.006c	0.000 ± 0.000	0.005 ± 0.006c
df		6, 34	6, 34	6, 34	6, 34	6, 34	6, 34	6, 34	6, 34	6, 34
F		7.517	2.038	6.44	1.035	4.113	1.809	4.301	3.097	4.247
		P<0.0001	P>0.05	P<0.0002	P>0.05	P<0.04	P>0.05	P<0.03	P>0.05	P<0.04

Means in the same column followed by the same letter are not significantly different (Tukey test on log(x+1) transformed data, *P*=0.05, non-transformed means shown

Table 4. Experiment 1: Mean (±SD) number of fruit flies per trap per day captured at Beau Bassin

Treatments (IP McPhail trap)	n	Mean ± SD insects / Trap / Day								
		B. zonata			C. capitata			C. rosa		
		Females	Males	Total	Females	Males	Total	Females	Males	Total
Torula	5	0.513 ± 0.260a	0.130 ± 0.058a	0.643 ± 0.312a	0.012 ± 0.002	0.004 ± 0.006	0.016 ± 0.005	0.327 ± 0.400	0.111 ± 0.131	0.438 ± 0.531
AA + TMA + PT	5	0.469 ± 0.189a	0.114 ± 0.051a	0.584 ± 0.239a	0.014 ± 0.009	0.010 ± 0.014	0.024 ± 0.023	0.374 ± 0.518	0.136 ± 0.179	0.510 ± 0.697
2AA		0.397 ± 0.179a	0.101 ± 0.061a	0.499 ± 0.238a	0.011 ± 0.016	0.005 ± 0.004	0.016 ± 0.019	0.112 ± 0.122	0.050 ± 0.040	0.162 ± 0.161
2AA + TMA	5	0.614 ± 0.299a	0.149 ± 0.050a	0.763 ± 0.331a	0.009 ± 0.010	0.003 ± 0.005	0.012 ± 0.014	0.265 ± 0.348	0.109 ± 0.134	0.374 ± 0.482
2AA + PT	5	0.420 ± 0.215a	0.105 ± 0.050a	0.525 ± 0.262a	0.015 ± 0.014	0.006 ± 0.009	0.021 ± 0.022	0.264 ± 0.330	0.097 ± 0.120	0.361 ± 0.450
Solbait	5	0.022 ± 0.036b	0.006 ± 0.009b	0.028 ± 0.045b	0.002 ± 0.005	0.001 ± 0.002	0.003 ± 0.006	0.049 ± 0.091	0.014 ± 0.022	0.062 ± 0.112
AA + TMA	5	0.405 ± 0.161a	0.131 ± 0.068a	0.536 ± 0.223a	0.013 ± 0.006	0.004 ± 0.000	0.016 ± 0.006	0.227 ± 0.294	0.085 ± 0.100	0.312 ± 0.394
GF120	5	0.019 ± 0.015b	0.005 ± 0.003b	0.024 ± 0.017b	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.024 ± 0.034	0.009 ± 0.014	0.032 ± 0.048
df		7, 39	7, 39	7, 39	7, 39	7, 39	7, 39	7, 39	7, 39	7, 39
F		8.405	7.044	9.253	1.748	1.1111	1.697	0.993	0.999	1.056
		P<0.000008	P<0.00004	P<0.000003	P>0.05	P>0.05	P>0.05	P>0.05	P>0.05	P>0.05

Means in the same column followed by the same letter are not significantly different (Tukey test on log(x+1) transformed data, *P*=0.05, non-transformed means shown

Table 5. Experiment 2: Mean (±SD) number of fruit flies per trap per day captured at Beau Bassin

Trap Type	Retention Device	Treatments / Baits	n	Mean ± SD insects / Trap / Day								
				B. zonata			C. capitata			C. rosa		
				Females	Males	Total	Females	Males	Total	Females	Males	Total
IPMT	Sticky insert	AA + TMA + PT	5	0.083 ± 0.037bc	0.028 ± 0.016ab	0.111 ± 0.051ab	0.005 ± 0.006	0.001 ± 0.002	0.006 ± 0.007	0.071 ± 0.038a	0.042 ± 0.046	0.113 ± 0.078a
Easy trap	Sticky insert	AA + TMA + PT	5	0.029 ± 0.011bc	0.006 ± 0.003b	0.036 ± 0.009b	0.005 ± 0.006	0.001 ± 0.002	0.006 ± 0.007	0.052 ± 0.029abc	0.021 ± 0.011	0.074 ± 0.034ab
IPMT	Water	Protein hydrolysate	5	0.020 ± 0.014c	0.004 ± 0.003b	0.024 ± 0.017b	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.001 ± 0.003c	0.002 ± 0.003	0.004 ± 0.005b
Coloured sphere	Sticky insert	AA + TMA + PT	5	0.002 ± 0.003c	0.001 ± 0.002b	0.003 ± 0.004b	0.001 ± 0.002	0.000 ± 0.000	0.001 ± 0.002	0.001 ± 0.002c	0.001 ± 0.003	0.003 ± 0.003b
IPMT	Water	AA + TMA + PT	5	0.248 ± 0.153a	0.060 ± 0.031a	0.308 ± 0.178a	0.006 ± 0.0006	0.001 ± 0.002	0.010 ± 0.006	0.059 ± 0.047ab	0.024 ± 0.021	0.084 ± 0.068ab
IPMT	Water	Waste Brewer's yeast	5	0.172 ± 0.120ab	0.058 ± 0.041a	0.231 ± 0.158a	0.001 ± 0.002	0.001 ± 0.003	0.002 ± 0.003	0.016 ± 0.013bc	0.006 ± 0.009	0.022 ± 0.020b
df				5, 29	5, 29	5, 29	5, 29	5, 29	5, 29	5, 29	5, 29	5, 29
F				7.817	7.606	8.46	1.858	0.725	1.987	6.419	2.856	5.671
				P<0.0002	P<0.0002	P<0.0001	P>0.05	P>0.05	P>0.05	P<0.001	P>0.05	P<0.01

Table 6. Experiment 2: Mean (±SD) number of fruit flies per trap per day captured at Pointe aux Sables

Trap Type	Retention Device	Treatments / Baits	n	Mean ± SD insects / Trap / Day								
				B. zonata			C. capitata			C. rosa		
				Females	Males	Total	Females	Males	Total	Females	Males	Total
IPMT	Sticky insert	AA + TMA + PT	5	0.016 ± 0.007b	0.004 ± 0.010b	0.021 ± 0.015b	0.014 ± 0.014ab	0.006 ± 0.009	0.020 ± 0.023ab	0.055 ± 0.054	0.021 ± 0.021	0.076 ± 0.076
Easy trap	Sticky insert	AA + TMA + PT	5	0.004 ± 0.004b	0.000 ± 0.000b	0.004 ± 0.004b	0.014 ± 0.014ab	0.004 ± 0.005	0.018 ± 0.018ab	0.059 ± 0.055	0.023 ± 0.028	0.081 ± 0.083
IPMT	Water	Protein hydrolysate	5	0.006 ± 0.005b	0.000 ± 0.000b	0.006 ± 0.005b	0.004 ± 0.005b	0.000 ± 0.000	0.004 ± 0.005b	0.016 ± 0.027	0.004 ± 0.008	0.019 ± 0.035
Coloured sphere	Sticky insert	AA + TMA + PT	5	0.006 ± 0.009b	0.001 ± 0.002b	0.006 ± 0.011b	0.000 ± 0.000b	0.001 ± 0.001	0.001 ± 0.002b	0.004 ± 0.005	0.000 ± 0.000	0.004 ± 0.005
IPMT	Water	AA + TMA + PT	5	0.089 ± 0.049a	0.019 ± 0.011a	0.108 ± 0.059a	0.043 ± 0.036a	0.014 ± 0.018	0.056 ± 0.053a	0.091 ± 0.113	0.041 ± 0.054	0.131 ± 0.166
df				4, 24	4, 24	4, 24	4, 24	4, 24	4, 24	4, 24	4, 24	4, 24
F				13.921	7.308	13.74	4.113	1.763	3.378	1.675	1.638	1.735
				P<0.00001	P<0.001	P<0.00002	P<0.014	P>0.05	P<0.029	P>0.05	P>0.05	P>0.05

Means in the same column followed by the same letter are not significantly different (Tukey test on log(x+1) transformed data, *P*=0.05, non-transformed means shown

ACKNOWLEDGEMENTS

This study was conducted within the framework of a research coordinated project supported by the research contract no.11178/R3 of the International Atomic Energy Agency and support from the Government of Mauritius.

REFERENCES

Allwood, A.J. (1997). Control strategies for fruit flies (Family Tephritidae) in the South Pacific. *Proceedings on the Management of fruit flies in the Pacific*, pp 171-178. (Eds A.J. Allwood and R.A.I. Drew). Nadi, Fiji.

Bateman, M.A. and Morton, T.C. (1981). The importance of ammonia in proteinaceous attractants for fruit flies (Family: Tephritidae). *Australian Journal of Agricultural Research* **32**, 883-903.

Economopoulos, A.P. (1989). Use of traps based on colour and/or shape. In: *World Crop Pests, Fruit Flies, Their Biology, Natural Enemies and Control Vol. 3B*, pp 315-327. (Eds A.S. Robinson and G. Hooper). Elsevier, Amsterdam.

Economopoulos, A.P. and Haniotakis, G.E. (1994). Advances in attractant and trapping technologies for tephritids. In: *Fruit flies and the Sterile Insect Technique*, pp 57-66. (Eds C.O. Calkins, W. Klassen and P. Liedo).

Epsky N.D., Hendrichs J., Katsoyannos B.I., Vasquez L.A., Ros J.P., Zumreoglu A., Pereira R., Bakri A., Seewooruthun SI and Heath R.R. (1999). Field evaluation of female-targeted trapping systems for *Ceratitis capitata* (Diptera: Tephritidae) in seven countries. *Journal of Economic Entomology*. **92**(1): 156-164.

Hammes C. (1980). Natal fruit fly. *Projet de lutte contre la mouche du Natal Pterandus rosa (Karsch), Diptera, Trypetidae a l'Ile Maurice. France: CIRAD*, pp 12-35.

Heath R.R., Epsky, N.D., Guzman, A. Dueben, B.D., Manukian, A. and Meyer, W.L. (1995). Development of a Dry Plastic Insect Trap baited with food-based synthetic attractant for the Mediterranean and Mexican fruit flies (Diptera: Tephritidae). *Journal of Economic Entomology* **88** (5), 1307-1315.

Heath R.R. Epsky, N.D., Dueben, B.D. and Meyer, W.L. (1996). Systems to monitor and suppress *Ceratitis capitata* (Diptera: Tephritidae) populations. *Florida Entomology*. **79**: 144-153.

Heath R.R., Epsky, N.D., Guzman, A. Dueben, Rizzo, J. and Jeronimo, F. (1997). Adding methyl-substituted ammonia derivatives to a food-based synthetic attractant on capture of the Mediterranean and Mexican fruit flies (Diptera: Tephritidae). *Journal of Economic Entomology* **90**: 1584-1589.

Katoyannos B.I. (1994). Evaluation of Mediterranean fruit fly traps for use in sterile-insect-technique programmes. *Journal of Applied Entomology*. **118**: 442-452.

Landell Mills (1991). Fruit fly control in Mauritius. *Report prepared for the Ministry of Economic Planning and Development, Government of Mauritius. Bath, UK: Landell Mills Ltd*, 155 pp.

Lopez, F.D., Steiner, L.F. and Holbrook, F.R. (1971). New yeast hydrolysate-borax bait for trapping the Caribbean fruit fly. *Journal of Economic Entomology* **64** (6), 1541-1543.

Morton, T.C. and Bateman, M.A. (1981). Chemical studies on proteinaceous attractants for fruit flies family tephritidae. *Australian Journal of Agricultural Research* **32**, 905-912.

Neilson, W.T.A., Knowlton, A.D. and Whitman, R.J. (1981). Capture of apple maggot adults on Pherocon, Rebell and sticky sphere traps. *Journal of Economic Entomology* **74**, 203-206.

Orian J.E.A. and Moutia L.A. (1960). Fruit flies (Trypetidae) of economic importance in Mauritius. *Revue agricole et Sucrière de l'Ile Maurice* **39** (3), 142-150.

Prokopy, R.J. and Roitberg, B.D. (1984). Foraging behavior of true fruit flies. *American Scientist* **72**, 41-49.