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Development of Improved Attractants and Their Integration into Fruit Fly SIT Management Programmes

Proceedings of a final Research Coordination Meeting organized by the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture and held in Vienna, 5-7 May 2005

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FOREWORD

Information provided by trapping systems is used to assess the presence, seasonal abundance, spatial distribution, host sequence and infestation levels of fruit fly pests. This information is key for implementation of effective fruit fly control programmes. Most trapping systems commercially available are based on para-pheromones which are male specific. These male specific trapping systems have been used as the main survey tool in area-wide fruit fly control programmes. Nevertheless, in recent years, scientists and programme managers have realized that, in order to improve the efficiency of fruit fly control, it is essential to have a female specific or at least a female biased trapping system. Until the late 1990s, the only fruit fly female biased attractants were based on natural protein baits such as Torula Yeast and hydrolysate proteins. Although these attractants tend to catch more females than males (in average 60% females against 40% males), the proportion in favor of females is insufficient and the attractants are considered to be weak and non-selective.

In 1999, as a result of a previous Coordinated Research Project (CRP) entitled "Development of Female Medfly Attractant Systems for Trapping and Sterility Assessment" the first effective female biased synthetic food lure was developed for the Mediterranean fruit fly (*Ceratitis capitata*, Wied.) (IAEA-TECDOC-1099). This lure, with the commercial name of Biolure, is now being used in large-scale medfly control programmes worldwide.

Given this background, and in order to further advance this field, the Joint FAO/IAEA Programme approved in 2000 a five year CRP entitled "Development of Improved Attractants and their Integration into Fruit Fly SIT Management Programmes". The research conducted under this CRP focused mainly on developing female biased trapping systems for other fruit fly species of quarantine and economic importance within the *Anastrepha, Bactrocera*, *Ceratitis* and *Dacus* genera and on optimization of current traping devices and the female biased attractant Biolure as well as on evaluation of mass trapping as a method for population suppression and development of target lure and kill devices or "bait stations" for fruit fly control and field evaluation procedures.

Through this CRP (2000–2005) and two previous CRP's, which results were published in IAEA-TECDOC-883, and IAEA-TECDOC-1099, on fruit fly trapping technology, significant progress has been made in optimization of current trapping systems and on developing female biased attractants for surveillance of some of the major fruit fly pests. Furthermore, a solid basis for continuing the development of bait stations has been established. However, there are still a number of information gaps that need to be filled through further research and development. These gaps have been clearly identified for future research efforts. This includes: (1) optimizing the use of the dry synthetic food attractants in relation to different climatic conditions, (2) continuation of the evaluation of detection systems for new exotic invasive fruit fly species, (3) basic research on more potent attractants for the olive fruit fly (*B. oleae*) and on the behaviour related with such attractants, (4) development of bait station that present a generic action, have low impact on non-target species (natural enemies and pollinators), be longlasting, inexpensive and biodegradable, and (5) studies on spatial and temporal dynamics of the populations for development of mass trapping and bait station technologies.

The setting of the CRP, with scientists from research institutions in 18 different Member States interacting with the manufacturers and suppliers of trapping materials and under the coordination of the Joint FAO/IAEA Programme, showed to be a very effective model to reduce the time period from the development of the technology to the commercialization and utilization by the end user.

The officer responsible for this publication was W. Enkerlin of the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture.

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SUMMARY

During a previous FAO/IAEA Coordinated Research Project (CRP) entitled "Development of Female Medfly Attractant Systems for Trapping and Sterility Assessment" conducted from 1995 to 1998, a female biased medfly trapping system was developed. This system is based on the combination of three synthetic food attractants: Ammonium Acetate, Putrescine and Thrimethylamine (Biolure®) [IAEA-TECDOC-1099]. This attractant is now being extensively used in area-wide Mediterranean fruit fly, *Ceratitis capitata*, Wied. (medfly) control programmes worldwide. With the availability of a female biased trapping system, medfly populations are detected earlier thus improving the effectiveness of suppression and eradication measures. In addition, in areas where only sterile males of genetic sexing strain are released, traps baited with the female biased attractant are used for detection of wild females, while a lower density of traps baited with male specific attractant Trimedlure are used to monitor the released sterile male flies. This improves the efficiency of sterile insect technique programmes as much less sterile males are captured in traps and a more sensitive female trapping system is in place reducing the need for intensive fruit sampling activities in areas where sterile males are released.

Based on the positive results obtained in the previous CRP, a new CRP for the period 2000 to 2005 entitled "Development of Improved Attractants and their Integration into Fruit Fly SIT Management Programmes" was implemented. The research conducted under this CRP mainly focused on two main areas: (a) Development of female biased trapping systems for fruit fly species (other than medfly) of quarantine and economic importance within the *Anastrepha, Bactrocera*, *Ceratitis* and *Dacus* genera and on oPTimising the use of the medfly attractant Biolure, (b) Evaluation of mass trapping as a method for population suppression and development of target lure and kill devices "bait stations" for fruit fly control and procedures for field evaluation of the lure and kill devices.

Twenty-one participants from 18 countries followed a standard research protocol developed within the CRP to evaluate trapping systems and bait stations under a wide-range of climatic and host conditions. In addition, participants conducted side experiments for testing of other promising traps, attractants and retention media (i.e. killing agents). Annex 1 presents a summary table showing a complete list of the attractants that were tested throughout the CRP. A total of 35 attractants, single and in combination, were field tested and the most relevant results obtained are summarized below.

1. TRAPPING SYSTEMS

1.1. Optimization of the medfly female biased synthetic food lure (Biolure)

The Problem:

Although the cost of the medfly female biased attractant Biolure has been reduced in the past few years, it is still expensive compared to the conventional male specific trapping system based on Trimedlure. Optimization of Biolure and cost reduction could be achieved by optimizing the concentration of the three components and assessing if, for certain applications, one of the components could be omitted.

Achievements:

- A two component lure based on Ammonium Acetate (AA) and Trimethylamine (TMA) was evaluated and results indicate that although not statistically equal compared with the commercial product Biolure (i.e. three component lure: Ammonium Acetate (AA), Trimethylamine (TMA) and Putrescine (PT)), the difference is slim. The two component lure attracts more female medflies than the conventional protein baits (Torula Yeast and hydrolysate protein) and it is much more selective. Thus this lure can be used for monitoring of medfly populations in programmes which aim at population suppression and establishment of low prevalence areas for which less sensitive trapping systems are sufficient. Eliminating one compound from the lure results in a cheaper product. Nevertheless for evaluating an eradication programme and for detection surveys in medfly free areas, the most effective lure continues to be the Biolure. This is true for prevailing climatic conditions in the Mediterranean Basin, Indian Ocean, tropical Africa, Central and South America.

1.2. Assessment of the range of attraction of other fruit flies to the medfly synthetic food lure (Biolure)

The Problem:

There is indication that, besides female and male medfly, Biolure attracts other fruit fly species of economic importance. Field tests are required to scientifically assess this information.

Achievements:

- It was determined that females and males of a number of other fruit flies of economic importance respond better to the Biolure (AA + TMA + PT) than to the conventional protein baits (Torula Yeast and hydrolysate protein). For these species the Biolure is also biased towards female catch as in the case of medfly. The species that respond to Biolure are the following:

Fruit Fly Species	Attractant	Location
Ceratitis cosyra (Mango Fruit Fly or Marula Fruit Fly)	Biolure (AA + TMA + PT)	Kenya
C. rosa (Natal Fruit Fly)	"	Mauritius, Reunion
C. fasciventris	"	Kenya
C. anonae	"	Kenya
Bactrocera zonata (Peach Fruit Fly)	"	Mauritius, Reunion
B. cucurbitae (Melon fly)	"	Mauritius, Reunion
B. invadens	"	Kenya
Dacus ciliatus (Ethiopian Fruit Fly)	"	Reunion

1.3. Development and evaluation of female biased attractants for other fruit fly species of economic importance

The Problem:

Apart from the medfly female biased Biolure, there are no other effective female biased attractants available for a number of fruit flies of economic importance.

Achievements:

- Different concentrations of AA in combination with TMA and PT proved to be better attractants compared with the conventional protein baits (Torula Yeast and hydrolysate protein) for some fruit flies of economic importance. The species, corresponding attractant and location are the following:

Fruit Fly Species	Attractant	Location
Bactrocera zonata (Peach Fruit Fly)	2AA 2AA + TMA AA + PT	Reunion Mauritius Pakistan
B. cucurbitae (Melon Fruit Fly)	2AA ½AA	Mauritius Reunion
Ceratitis cosyra (Mango Fruit Fly or Marula Fruit Fly), *C. rosa* (Natal Fruit Fly), *C. fasciventris, C. anonae*	AA + TMA	Mauritius and Reunion
Dacus ciliatus (Ethiopian Fruit Fly)	½AA 2AA	Mauritius and Reunion

- For *Anastrepha ludens* (Mexican Fruit Fly), *A. serpentina* (Sapote Fruit Fly) and *A. obliqua* (West Indian Fruit Fly), under subtropical conditions during the dry season (lower relative humidity and higher temperature) in Colombia, Mexico, and Honduras, the two component lure (AA and PT) was equally or more effective compared with the conventional protein baits (Torula Yeast and NuLure). However, in these same places but during the rainy season (higher relative humidity and lower temperature) the conventional protein baits continue to be the most effective. Considering that the synthetic lures are easier to handle, more selective and tend to be more consistent than Torula Yeast and NuLure, these attractants are considered to be a better choice under dry and hot conditions. Cost of synthetic food lures are higher than the cost of the conventional protein baits, however, a cost analysis should take into consideration the fact that the synthetic food lures are less labour intensive and longer lasting.

- For *B. oleae* (olive fly) the best attractant both for monitoring and detection was NuLure/borax. This captured significantly more flies than the conventional Ammonium Bicarbonate and Spiroketol. This attractant could be used with McPhail type traps such as the Tephri and Multilure, and other traps such as the Easy trap.

1.4. Optimizing the use of trap devices and alternative retention mediums

The Problem:

A number of commercial trapping devices and fruit fly retention mediums (dry and liquid) that are available in the market need optimization. Moreover, DDVP, one of the commonly used retention mediums in dry traps, has been phased out in various countries of the EU. OPTimisation of trapping devices and finding alternative mediums would increase cost-effectiveness of trapping networks.

Achievements:

- It has been demonstrated that the Multilure trap is more cost-effective than the glass McPhail trap. Its design allows for easy trap service and is longer lasting since it is made of hard plastic material. Furthermore, its versatility in the use of various liquid and dry attractants provides the trap with an additional advantage. This is true for climatic conditions in Central and South America and the Indian Ocean, and for *Anastrepha spp*., *Bactrocera spp*. and *Ceratitis spp.*

- Furthermore, under Mediterranean climatic conditions for *C. capitata*, the Tephri trap used dry or liquid is the most functional, although the Multilure trap has shown also a good performance.

- It has been demonstrated that liquid retention systems based on water and Triton (1 drop/litre of water) are a good option in combination with the synthetic food lures Biolure and the two component lure (Ammonium Acetate and Putrescine) in a Multilure trap. This is true for climatic conditions in Central and South America and the Indian Ocean and for *Anastrepha spp*., *Bactrocera spp*. and *Ceratitis spp.*

- For traps using dry retention systems such as the Tephri trap used in the Mediterranean Basin and the Multilure trap used in the Americas, Deltamethrinee (DM) expanded polyethylene strip (Scalibur®) 25 cm long and the DM impregnated mosquito nets (PermaNet 75®) have shown to be as good as the conventional DDVP retention system. These DM based options have the advantage that DM is registered for use in organic agriculture when it is contained in a device such as traps. Furthermore, the DM impregnated nets due to their formulation and UV-light protection, retain the toxic effect for at least 6 months under field conditions making this option less expensive than the DDVP. DDVP has been phased-out for use in organic agriculture. In addition there is data indicating that DDVP has a repellent effect on fruit flies probably due to its low vapour pressure.

2. EVALUATION OF MASS TRAPPING AND DEVELOPMENT OF LURE AND KILL DEVICES OR "BAIT STATIONS"

2.1 Evaluation of mass trapping for fruit fly population suppression

The Problem:

Mass trapping is known to be a method with potential for fruit fly population suppression to protect high value crops which are sold for example in the organic market. Cost-effectiveness needs to be improved before its use can be expanded.

Achievements:

- Mass trapping is an expensive fruit fly control method that can be used under limited situations where benefits clearly outweigh the costs. McPhail type traps such as Tephri traps baited with AA and TMA, and the cheaper Easy trap baited with the same attractants can be used. Substituting DDVP with Deltamethrinee impregnated nets can reduce cost and increase effectiveness. However, the dispersion behavior and host sequence of fruit flies need to be carefully assessed in order to deploy traps at the right time of the year when populations are starting to build up. This information is also relevant to assess the spatial distribution of the traps within the area being protected. This is crucial for effective population suppression using mass trapping.

2.2 Development and field evaluation of lure and kill devices or "bait stations"

The Problem:

Lure and kill devices known as "bait stations" are needed as environment-friendly tools for fruit fly population suppression mainly in backyards, in rural and suburban areas, in difficult to access terrain and in protected natural areas. At present time there is no cost-effective bait station available.

Achievements:

- Results obtained indicate that there is significant potential in the use of bait station techniques. Experiments in Argentina using bait stations developed by Quest with the name of M3 and a bait station developed by USDA-ARS (Dr. Robert Heath) showed to be effective for suppressing medfly populations and protecting citrus fruits. Results based on level of fruit infestation indicate that the bait stations are as effective as the conventional ground bait sprays (i.e. mixture of Malathion 100E 0.1%, hydrolysate protein 5% (NuLure) and water). In the case of the M3, one bait station was used per tree and in the case of the USDA-ARS bait station one every second tree. Bait stations provided protection for four months, which covers the fruiting season of citrus. Furthermore, in the Mediterranean Basin (Spain and Greece), promising results were obtained with yellow spheres internally baited with AA + TMA and coated with sugar and Methomyl. The cost of using the bait stations should be assessed and compared against the costs of conventional control using bait sprays. Even though progress has been made, more work is required in order to be able to recommend cost-effective baits stations for use in area-wide action programmes.

2.3 Development of methodologies for field evaluation of lure and kill devices or "bait stations"

The Problem:

No standard methodologies are available for evaluating lure and kill devices in the field.

Achievements:

- Standard methodologies for evaluation of bait stations in the field were developed and used. Given that the bait stations are not designed to catch fruit flies but instead to lure and kill them, evaluation of the effect of the bait stations has to be conducted based on a statistical fruit sampling procedure. Fruit sampling procedures need to be further developed and incorporated into bait station research protocols.

As a result of the experimental work carried out during the CRP, a total of 52 scientific papers were prepared by the CRP participants. Of these, 37 were published in peer reviewed journals and books and 15 are in press or were submitted for publication (Annex 2).

FRUIT FLY TRAPPING AND CONTROL — PAST, PRESENT AND FUTURE

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Abstract

Fruit fly trapping has a long, well documented history that has led to the development of numerous trap and lure combinations that are used throughout the world for pest tephritid fruit flies. The International Atomic Energy Agency (IAEA), through its Joint FAO and IAEA Programme, has supported development of female-targeted trapping systems for use with the sterile insect technique through funding of several Coordinated Research Projects (CRPs) that have led to the current CRP. Results of research conducted under a CRP on "Standardization of Medfly Trapping for Use in Sterile Insect Technique Programmes" determined that plastic McPhail traps, specifically International Pheromones McPhail traps (IPMT), baited with liquid protein solutions were the recommended female-targeted trapping system for medflies [1]. At this time, R. Heath and N. Epsky were conducting research on effect of formulations of the liquid protein bait NuLure/borax on medfly and mexfly caPTure in Guatemala [2]. Chemical analysis paired with laboratory bioassays and field tests resulted in the development of a two-component synthetic food-based lure comprised of ammonium acetate (FFA) and putrescine (FFP), and a closed-bottom dry trap that protected the lures from the environment [3]. Depending on dosage of the attractants, caPTure in these traps tended to be equal to caPTure in liquid protein-baited McPhail traps although they captured fewer male medflies than Trimedlure (TML)-baited Jackson traps.

1. FRUIT FLY TRAPPING: PAST

A presentation of these results by R. Heath to D. Lindquist at a less than formal setting elicited an adamant opinion from D. Lindquist that this should be pursued. The response by R. Heath was "What the heck are you talking about? There isn't anything to pursue yet. We are still in the basic aspect of the research." D. Lindquist replied "It doesn't matter. We are going to have a full scale, multinational programme to pursue this work." Subsequent travel by R. Heath and N. Epsky to Vienna laid the groundwork for developing the protocol for the first year of the CRP "Development of Female Medfly Attractant Systems for Trapping and Sterility Assessment." For year one of the CRP, research compared caPTure in the closed-bottom dry trap baited with FFA + FFP with caPTure in the Jackson trap with TML (standard male-targeted trapping system). Results of the year one field tests were presented at the 1st Research Coordination Meeting (RCM) in Antigua, Guatemala in 1995. Participants included A. Bakri, Morocco; H. Camacho, Costa Rica; N. Epsky, USA; R. Heath, USA; J. Hendrichs, Vienna; N. Kouloussis, Greece; R. Pereira, Portugal; P. Rendon, Guatemala; J.P. Ros Amador, Spain; J. Rull, Mexico; K. Sponagel, Honduras; E. Vattuone, Argentina; and A. Zümreöglu, Turkey. The first year results supported the statements by R. Heath. Although many were enthusiastic to continue this dismal approach, there were representatives in a more honest frame that simply stated "This is a waste of my time!" Problems with the new trapping system included very poor caPTure in tests conducted in the Mediterranean region, difficulty in recovering flies, and predation of flies in the traps by wasps. However, although the total number of medflies captured by the new system tended to be much lower than by the TML traps, female medflies were captured. Ongoing research in Guatemala resulted in the development of an open-bottom dry trap with FFA + FFP that is used with a yellow sticky insert (phase 4 trap) [4]. Based on the year one results, the year two protocol compared the following traps and lures: closed-bottom dry trap, open-bottom dry trap and IPMT baited with FFA +

FFP, IPMT baited with NuLure/borax (standard female-targeted trapping system), and Jackson trap with TML. IPMT traps with FFA + FFP used an aqueous borax solution to retain captured flies, and use of the synthetic attractant in a wet trap overcame problems encountered in the Mediterranean region and improved caPTure of female medflies.

In continuing research in Guatemala, R. Heath and N. Epsky found that trimethylamine (FFT) is a potent synergist to FFA + FFP for caPTure of medflies [5]. A license was obtained and commercial production of FFA + FFP + FFT as BioLure 3-Component Fruit Fly Lure (Suterra LLC, Bend, Oregon, USA) was initiated. The year three protocol for the CRP tested the following: open-bottom dry trap and IPMT with FFA + FFP and FFA + FFP + TMA; IPMT with NuLure/borax; Frutect trap with protein bait (from Israel); and Jackson trap with TML. Results of year two and year three research were presented at the 2nd RCM in Madeira, Portugal in 1997. Participants included A. Bakri, Morocco; H. Camacho, Costa Rica; N. Epsky, USA; R. Heath, USA; Y. Gazit, Israel; J. Hendrichs, Vienna; P. Howse, England; B. Katsoyannos, Greece; D. Lindquist, Vienna; N. Papadopoulos, Greece; R. Pereira, Portugal; P. Rendon, Guatemala; J. P. Ros Amador, Spain ; Y. Rössler, Israel; J. Rull, Mexico; S. Seewooruthun, Mauritius; L. Vasquez, Honduras; E. Vattuone, Argentina; A. Zümreöglu, Turkey. We had a very productive and positive RCM, and the small number of naysayers of the synthetic lure became followers with the addition of trimethylamine. From this point on, in spite of inclement weather, there appeared to always be a rainbow over this project.

Year four of the CRP evaluated trap type and retention system combinations with FFA + FFP + FFT, including IPMT and Tephri-trap (from Spain) as wet traps (with aqueous triton solution) or dry traps (with DDVP) in comparison with IPMT with NuLure/borax. The 3rd and final RCM was held in Penang, Malaysia in 1998. Overall, conclusions on medfly caPTure from the CRP were that the two component BioLure was equal to liquid protein baits; addition of trimethylamine significantly improved medfly caPTure; the three component BioLure lasted for 6-8 weeks; BioLure-baited traps captured fewer non target insects; BioLure-baited traps captured 5-40 times fewer sterile flies; females could be captured live in traps and used for fertility assessment [6]; and, in low populations, BioLure-baited traps captured ~4 times more medflies than liquid protein-baited traps [7] and detected medflies 4 weeks earlier than TML-baited traps [8]. IAEA-TECDOC 1099 presents the proceedings of the final RCM for this CRP.

2. FRUIT FLY TRAPPING: PRESENT

With the successful completion of the CRP and the demonstration of the efficacy of the three component BioLure for medflies, research turned towards the development of new control strategies using these attractant chemicals. One approach was mass-trapping and this approach was demonstrated to be effective in tests by A. Economopoulos in Greece, Suterra LLC in Spain and J.P. Ros in Spain. Use of BioLure was facilitated by the development of the Multi-Lure Trap (Better World Manufacturing Inc., Fresno, California, USA). Interest also turned toward the development of target devices and bait stations as attract-and-kill systems that could be used in the place of traditional bait sprays. R. Mangan in collaboration with D. Moreno at Weslaco, Texas, used an approach that resulted in development of spinosad bait spray (GF-120) to develop bait stations that used formulated protein attractant [9]. The closed-bottom dry trap used a toxicant patch developed by R. Heath to kill attracted flies, and he developed a weather-resistant formulation that could be used as a bait station.

Other challenges remained from the CRP. Although medfly caPTure was targeted, tests of numerous *Ceratitis*, *Anastrepha* and *Bactrocera* spp. were included in the results. It was determined that more effective attractants were needed for species without parapheromones or effective female attractant. For example, the best baits for olive fruit fly still captured low numbers, and relative caPTure of *Anastrepha* species among baits/lures was highly variable and/or overall caPTure was very low. Thus improved attractants are needed for these species. Therefore, the protocols for the current CRP entitled “Development of Improved Attractants and their Integration into Fruit Fly SIT Management Programmes” were developed by R. Heath, R. Mangan and the CRP participants to address the development of improved traps and lures by evaluating synthetic lure dosage and/or formulations and/or alternative trapping systems, as well as testing newly developed bait stations and target devices. The results of this CRP are presented in this document.

Research activities continue at the Subtropical Horticulture Research Station (SHRS) in response to questions on chemical longevity of the lures, and the release rates and ratios of the synthetic attractants. New analytical methods were developed using Fourier transform infrared (FTIR) spectroscopy to quantify ammonia from lures [10]. Other lines of research include using electroantennogram (EAG), a technique that measures response of antennal olfactory recePTors to volatile chemicals. Although the technology has been available for decades, EAG typically has been used as a screening tool to confirm biological activity of candidate compounds. Recent improvements in quantification of chemorecePTive responses provide a new framework for comparative evaluation of potential attractants [11] and a basis for determination of how antennal recePTivity is affected by insect physiological state (e.g. sex, age, reproductive status)[12]. Also, spatial analysis of trapping data is being used to evaluate insect movement [13] and trapping efficacy.

3. FRUIT FLY TRAPPING: FUTURE

To solve the challenges that remain will require continued partnership among scientists, action agencies, growers and industry. This is best facilitated by an international agency. Mechanisms for this partnership include meetings such as the International Fruit Fly Symposium, the Working Group on Fruit Flies of the Western Hemisphere, and the newly formed Tephritid Workers of Europe Africa and the Middle East (TEAM). Questions for scientists include dose/ratios of components and effective trapping range for BioLure, identification of new attractant chemicals, bait stations, among others. Participation by action agencies, growers and industry includes growers as the stakeholders, action agencies responding to industry needs, accePTance by trading countries, and research as the major avenue of quarantine security. Involvement by international agencies is needed because the scope of research is great, a global approach is required, and the impact of success is global. Continued leadership as best exemplified by FAO/IAEA and specifically by D. Lindquist, J. Hendrichs and W. Enkerlin, is pivotal to the success of future global scientific endeavors. The magnitude of the needed global organization is far beyond the scope of most institutes. The demonstrated coordination by FAO/IAEA mandates the recognition and resources to address problems and provide solutions that will have positive global impact.

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DELTAMETHRINEE AS A REPLACEMENT FOR DICLORVOS (DDVP) STRIPS USED AS A RETENTION SYSTEM IN FRUIT FLY TRAPS

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Abstract

A side experiment was carried out as part of the Co-ordinated Research Project for the Development of Improved Attractants and their Integration into Fruit Fly SIT Management Programmes sponsored by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture of the International Atomic Energy Agency (IAEA). The aim was to find an effective substitute for the organophosphate Diclorvos (DDVP) strips used as killing agent in fruit fly traps. Several types of Deltamethrine (DM) impregnated devices were tested as fruit fly retention systems. One of the main problems faced today in fruit fly surveys is that the DDVP, which performs very well when used inside traps baited with female attractants and has a relatively long effectiveness, has been forbidden for use in organic farming and is on the list of insecticides to be phased out soon. The pyrethroid DM, which is permitted in organic farming, promises to be a good substitute. Field experiments were carried out testing two DM impregnated devices: Scalibor® (Intervet International B.V), a product that is commercially available in the form of anti-tick dog collars and PermaNet® 75 (Vestergaard Frandsen A/S), usually used to control some pest disease vectors such as malaria-bearing mosquitoes. The DM impregnated devices were placed inside Multilure (MLT) and Tephri traps (i.e. McPhail type), both baited with dry synthetic food lure (Biolure®), a *Ceratitis capitata* (Wied) female-biased attractant. The Israeli trap, which does not require a retention system, was also tested. Results show that although the Tephri trap baited with Biolure and DDVP as a retention system was the most effective in terms of average female captured, the MLT trap baited with Biolure and the DM PermaNet as a retention system is more cost-effective as, statistically, it Captures the same amount of females and in addition it is substantially cheaper, with a much longer toxic effect (up to one year) and more selective in terms of Captures of non-target organisms. The Tephri trap with Biolure and DM Scalibor as a retention system was the next best treatment as it is statistically equal than the previous two and more less equal in cost compared with the conventional Tephri trap baited with Biolure and DDVP. In our opinion, both retention systems could be good DDVP substitutes for use in fruit fly survey programmes.

1. INTRODUCTION

The organophosphate insecticide Diclorvos (DDVP: 2,2 Dichlorovinyl dimethyl phosphate) is used in fruit fly surveys and performs very well when used inside traps as a killing agent. However, this insecticide is forbidden for use in organic farming and is currently on the list of compounds to be phased out, therefore, finding a suitable substitute is one of the most pressing problems to be addressed in the area of fruit fly trapping. As a part of a series of side experiments carried out within the Co-ordinated Research Project: Development of Improved Attractants and their Integration into Fruit Fly SIT Management Programmes sponsored by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, of the International Atomic Energy Agency (IAEA), several field trials were carried out to find a solution to this problem.

Throughout this study, Deltamethrine (DM), a pyrethroid which is permitted in organic farming, was tested as a DDVP substitute in two DM-impregnated devices (Scalibor (Intervet International B.V) and PermaNet 75 (Vestergaard Frandsen A/S)). Scalibor is a product that is commercially available in the form of anti-tick dog collars and PermaNet 75 is usually employed to control some vectors of disease [6]. The aim was to test the efficiency of these commercial DM products, usually employed for control of non-agricultural pests, for management of agricultural pests. Both were placed inside fruit fly traps (i.e. Multilure trap and the Tephri trap), each baited with a medfly (*Ceratitis capitata,* Wied) female-biased solid synthetic food attractant (Biolure) developed [1] and improved by various authors [3] [4] [5]. In addition to the performance in terms of female catches, consideration was also given to the DM effectiveness over time (i.e. residual effect) as well as the cost. With this the cost-effectiveness of the various products was assessed, which is essential for decision making on the most suitable product to use [7] [8] [9] [10] [11] [12].

2. MATERIAL AND METHODS

2.1. Plot Selection

Two experiments were done in a 0.8 ha organically farmed citrus orchard, surrounded by vegetable crops, almond orchards and scattered farm-houses. The plot was located 7.5 km to the northwest of Palma, at sea level. The orange variety was predominately Navel late, although some tangerines and several lemon trees were also present.

2.2. First experiment

A 30 day experiment to test a commercial DM impregnated device (Scalibor® strips), was carried out from 15th November to 15th December 2003.

2.2.1. Traps and treatments

Tephri traps (i.e. McPhail type from Sorigar Ltd.) were baited with Biolure (Biolure®: Ammonium Acetate, Trimethylamine and Putrescine from Suterra) a dry synthetic food lure used as a medfly female biased attractant. Different length strips of expanded polyethylene Scalibor with 0.76 g of DM, were placed inside the traps. This strip is commercially marketed for flea control in dogs and is reported to be effective for 6 months, although some previous studies proved that this compound has an effective life span of up to one year.

FIG. 1. Photograph of a piece Scalibor® strip inside Tephri trap.

To determine the most effective size of the Scalibor strips, this porous and flexible plastic strip, 11 cm wide x 3.5 mm thick, was cut into three different lengths: 32.5 cm, 16 cm and 8 cm, each placed over the plastic platform located on the upper part of the trap that holds the small plastic container (basket) where Trimedlure, Methyleugenol and Cuelure plugs are kept (FIG. 1).

The experiment was arranged in 5 rows of 4 Tephri traps, one trap for each different size of Scalibor strip used and an additional trap containing a DDVP plug used as a control. All trap combinations were distributed in a random block design. Captures were recorded weekly and traps were rotated after each check. Data was transformed into mean number of males and females per trap per day (FTD).

2.3. A second experiment

This experiment was carried out to compare Scalibor with the PermaNet® 75. This is a DM impregnated white polyester net with 25 openings/cm^2 and has proven to be very effective in controlling vectors of disease such as the Tse-tse fly and the *Anopheles spp.* mosquito. The DM residual effect lasts up to 12 months. The field experiment was conducted from September 28th to November 3ed, 2004 (36 days).

2.3.1. Traps and treatments

Multilure (MTL; from Better World) and Tephri traps, each baited with Biolure, were used together with the two DM retention systems. A MTL trap with water/Triton and a Tephri trap with DDVP plug were used as controls. Each retention system was used as follows:

(a) A 32.5 cm piece of a Scalibor strip (the length that gave the best performance in experiment number one) was suspended from one of the following two support systems:
   i) the inner top of the MTL trap with a metallic clip;
   ii) placed on the upper plastic platform inside the Tephri trap.

(b) The PermaNet system was cut into the shapes shown in FIG. 2.

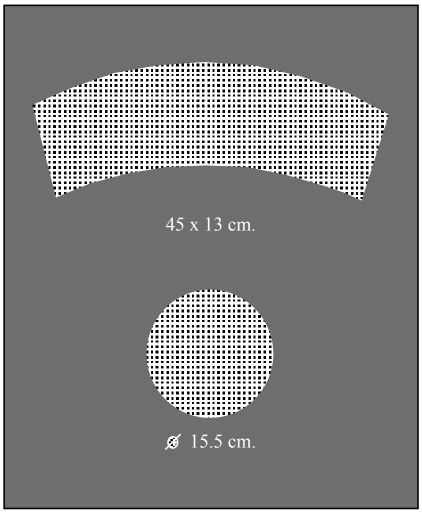

FIG. 2. White PermaNet® pieces used inside the Multilure (upper piece) and Tephri (bottom piece) traps.

The shape and size of the net was based on the shape and dimensions of the trap as follows:

(i) a piece in the shape of a truncated cone, 45 x 13 cm was used in the MTL trap. This cone was fixed with Velcro™ alongside the interior of trap walls;
(ii) for the Tephri trap, a circle-shaped piece of 15.5 cm in diameter was used. The circle was placed inside the trap using Velcro adhesive (FIG. 2).

Seven treatments (trapping systems), including the MTL trap with water and Triton as a control, were tested as shown in Table I. The Israeli-designed trap (Shabtiely trap), which does not require a retention system, was also tested.

TABLE I. TRAPS, ATTRACTANTS AND RETENTION SYSTEMS ASSAYED.

Treatments	Trap	Attractants	Retention sytem
A	MTL Trap	Biolure	Water/Triton
B	MTL Trap	Biolure	PermaNet
C	MTL Trap	Biolure	Scalibor
D	Tephri trap	Biolure	DDVP
E	Tephri trap	Biolure	PermaNet
F	Tephri trap	Biolure	Scalibor
G	Israeli trap	Biolure	None

Traps were distributed in a random block design, which included 7 treatments repeated in 5 blocks. Captures were recorded twice a week, separating males and females and also counting any other insects captured, apart from the medfly. After checking all the traps in one row, they were rotated clockwise.

2.4. Data Analysis

Data was summarized as follows:

- the mean number of males, females and total flies per trap per day
- the relative trap efficiency for males, females and the total number of flies captured in the traps
- the percentage of females in the total number of flies captured in each trap
- analysis of variance using data from all traps
- correlation analysis between number of flies captured and each of the environmental variables

Meteorological data was provided by the National Meteorological Service Station. The weather station was located about 5 km from the orchard used throughout the experiment.

3. RESULTS AND DISCUSSION

3.1. First Experiment

The Results showed that the Tephri trap with a 32.5 cm long strip captured more than the control (Tephri trap with DDVP), which has always been the best of all the other trap/treatments assayed in previous years [13]. It was also found that the decrease in the number of flies captured was directly correlated to the decrease in the length of the strip (Table II).

TABLE II. COMPARATIVE CAPTURES OBTAINED BY DIFFERENT LENGTHS OF DM SCALIBOR STRIPS AND THE CONVENTIONAL INSECTICIDE DDVP.

Retention system	Fe males		Ma les	
	Mean/trap	Females/trap/day	Mean/trap	Males/trap/day
Scalibor 32.5 cm	66	2.20	9	0.30
Scalibor 16 cm	21	0.70	1	0.03
Scalibor 8 cm	13	0.43	1	0.03
DDVP	51	1.70	6	0.20

3.2. Second Experiment

The second experiment was conducted during the second maximum peak of the *C. capitata* population, which took place in autumn. Initial Captures increased from 5.4 to 8.7 females/trap/day (FTD) during mid October, but dropped to 1.8 females/trap/day (FTD) by the end of the experiment in November, when temperatures dropped as a result of the winter.

3.2.1. Female Captures

Total female Captures expressed in FTD (Table III) showed that treatment D (Tephri trap with DDVP), traditionally the most effective trapping system for our local conditions [14] [15]), was again the best. This was followed by treatments B (MTL with PermaNet), F (Tephri with Scalibor strip) and E (Tephri with PermaNet), with no statistical difference. It should be noted that treatments B, F and E performed better than A (Multilure with water/Triton), which is the standard treatment used in all experiments reported in the Joint FAO/IAEA co-ordinated research protocols.

All treatments showed great variation throughout the experiment, as shown in FIG. 3

TABLE III. RANKING OF *C. CAPITATA* FTD CAPTURED BY THE DIFFERENT TREATMENTS.

Trap	Retention system	Treatment	Female/trap/day[1, 2]
Tephri trap	DDVP	D	8.46a
MTL trap	PermaNet	B	5.93a
Tephri trap	Scalibor	F	5.61a
Tephri trap	PermaNet	E	5.01a
Israeli trap	None	G	4.74a
MTL trap	Water/Triton	A	3.97a
MTL trap	Scalibor	C	3.93a

[1]Values followed by the same letters are not significantly different.

[2](ANOVA LSD multiple range text on long (x+1) transformed data. P= 0.05).

Treatment D (Tephri trap+DDVP) gave the most consistent performance. Treatment B worked very well during the second week and had a relatively accePTable performance during the third week, although the performance during the first week was poor. Treatment F was the second best during the first week, but performed poor the following week and recovered on the third, with even better results than treatment D. Treatments C and E showed more uniform numbers of captures throughout the experiment, although E was slightly better than C. In contrast, G, the Israeli trap, did not work as well as was expected. It had previously shown a good performance in experiments conducted by the group. During the month of November, the cooler temperatures caused the medfly population to decrease, and so minimising the differences between traps; although this did not alter the ranking between the treatments that remained similar to that of the month of October. Performance ranking, from best to worst for the month of November was: D, B, E, F, G, A and C.

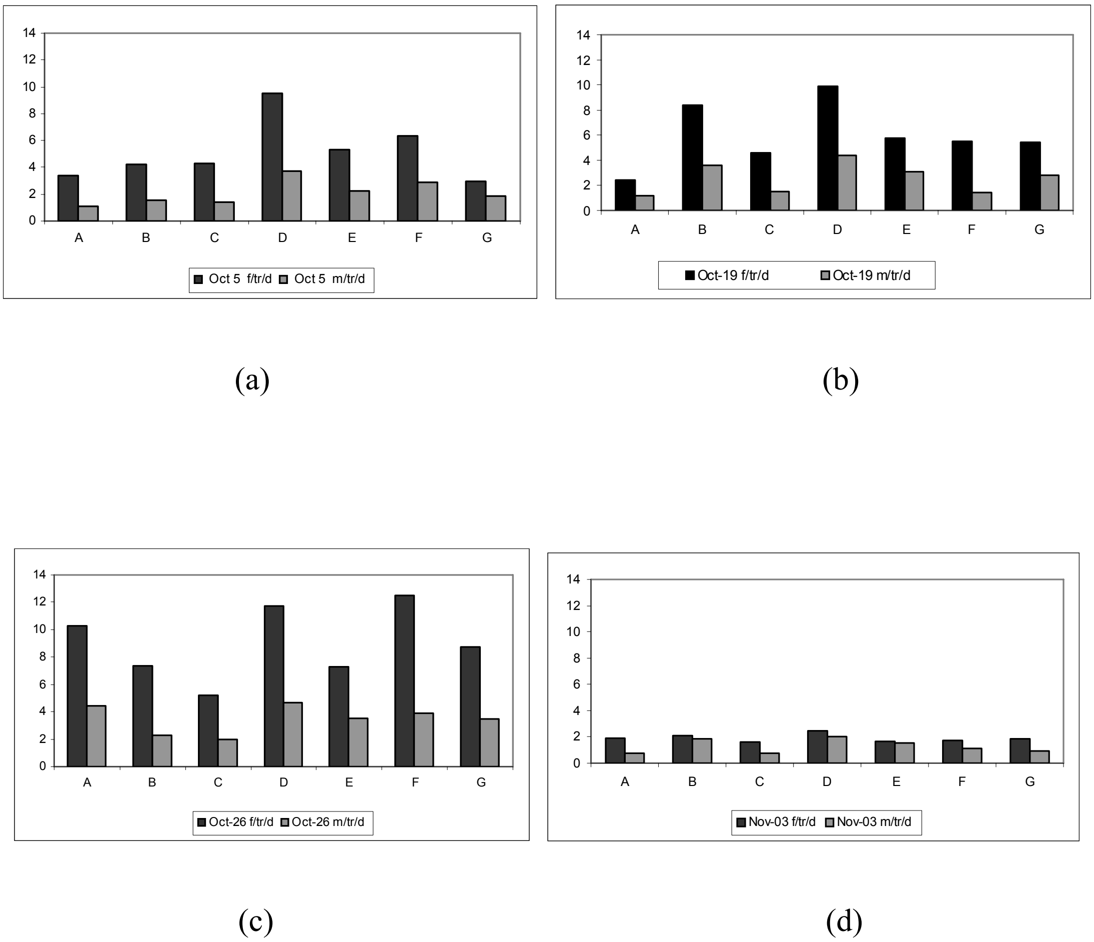

FIG. 3. Weekly female and male/trap/day captures obtained with the different treatments.

In summary, apart from the control treatment D (i.e. Tephri trap plus DDVP), treatments B and F obtained the best results during two weeks, thus resulting in the highest mean FTD Captures compared with the other treatments. The PermaNet fabric used inside the MTL type trap was the most effective, while the Scalibor strip had the best performance in the Tephri trap.

3.2.2. Relative efficiency for female captures

Results (Table IV) show that treatment D (Tephri with DDVP) obtained the best performance again capturing 22.7% of the total females per trap per day. This treatment was followed again by treatment B (MTL with PermaNet; 15.75 %) and this by F (Tephri with Scalibur; 14.9%).

Looking at the proportion of females captured in each treatment, all treatments captured more females than males with the highest being F (Tephri with Scalibur) capturing 74% females followed by C (MLT with Scalibur) with 73.7% and B (MTL with PermaNet) with 70.4%.

TABLE IV. RELATIVE TRAP EFFICIENCY AND PERCENTAGE OF FEMALES IN TOTAL NUMBER OF FLIES CAPTURED, SHOWING THE MEAN (#) OF MALE AND FEMALES, THE PERCENTAGE (%) OF MALE AND FEMALE CAPTURED PER TRAP PER DAY, AND THE PERCENTAGE (%FEMALE/TRAP) OF TOTAL (#FEMALES/# TOT) FEMALE CAPTURED AMONG ALL TRAPS. BEST PERFORMANCES ARE SET IN BOLD FACE TYPE.

	Avg. Flies per Trap per Day			% Avg. Flies per Trap per Day			% Fem/trap
Trap/Treat	# Males	# Females	# Total	% Males	% Females	% Total	(#fem/ #tot)
A	1.68	3.97	5.65	10.37	10.54	10.49	70.27
B	2.49	5.93	8.42	15.37	15.75	15.64	70.43
C	1.4	3.93	5.33	8.64	10.44	9.9	73.73
D	3.72	8.46	12.18	22.96	22.47	22.62	69.46
E	2.62	5.01	7.63	16.17	13.31	14.17	65.66
F	1.97	5.61	7.58	12.16	14.9	14.08	74.01
G	2.32	4.74	7.06	14.32	12.59	13.11	67.14
Total	16.2	37.65	53.85	100	100	100	

3.2.3. Captures of non-target insects

Results showed that insects of the order DiPTera were the most attracted to the traps (Table V). The Tephri trap with DDVP (Treatment D**),** caught the highest total number of Arthropoda, although A (MLT trap with water/Triton) proved to be the most harmful to beneficial fauna, while the remaining treatments showed similar low captures, but always lower than A. Treatments B and G proved to be the less harmful to beneficial fauna.

TABLE V. TOTAL CAPTURES OF NON-TARGET ORGANISMS DURING THE FIELD TRIAL.

Captures	Treat A	Treat B	Treat C	Treat D	Treat E	Treat F	Treat G	TOTAL
Beneficial Fauna	9	0	3	3	1	4	0	20
Total Arthropoda	71	52	46	139	60	44	20	432

3.2.4. Economic assessment

The average cost and effectiveness of each treatment is summarised in Table VI. This data shows that the MLT trap with PermaNet is the cheapest treatment based on cost of the net (3.5 cheaper) and duration (residual effect of DM 4 times longer). If we consider that this treatment was not statistically different than the Tephri trap with DDVP, we can conclude that the MLT trap and PermaNet is the most cost-effective treatment. Although the Scalibor strip is almost 4 times more expensive than the DDVP, it is also 4 times more durable. These two treatments are not statistically different in female Captures thus it can be said that cost-effectiveness of these two treatments is the same.

TABLE VI. COMPARISON BETWEEN THE COST AND EFFECTIVENESS OF THE THREE RETENTION SYSTEMS TESTED.

Retention system	Unit Price in Euros	Duration (residual effect)
DDVP	1.40	3 months
PermaNet	0.40	1 year
Scalibor	5.49	1 year

4. CONCLUSIONS

Despite of the better results obtained by one of the most widely used traps in the Western Mediterranean area (i.e. Tephri trap with Biolure and DDVP), both the MLT trap with PermaNet and the Tephri trap with Scalibor performed well , with no statistical differences among them. Both of them performed better than the MTL with water/Triton, which is the standard treatment used as a control in this CRP.

PermaNet performed best when used with a MTL trap. This result implies a substantial improvement, as a dry MTL is much easier to use and handle than a wet system (water and Triton as a retention system). In addition, no captures of non-target insects including beneficial insects were recorded with this system.

In addition PermaNet proved to be the most cost-effective system as the net is substantially cheaper more durable in terms of residual effect and statistically equally effective in female captures.

With respect to Tephri trap, the 32.5 cm Scalibor strip may be a good Diclorvos replacement, obtaining the third highest number of the average medfly female captures (5.6 females/trap/day), showing no statistical difference compared with the best two treatments. However, the advantage of this system is its longer lasting residual effect (4 times longer) and the reduced captures of beneficial insects compared with the conventional Tephri trap with DDVP. The strip of 32.5 cm is also slightly cheaper than DDVP plug.

The Israeli trap with no retention system performed poorly.

Further research on substitutes for DDVP is needed before final conclusions can be drawn. Nevertheless, equal percent of females captured, longer lasting effectiveness, lower cost (in the case of the PermaNet) and lower captures of non-target insects, make DM in both presentations (PermaNet and Scalibor strip) an accePTable alternative to DDVP and with the possibility for use also in organic farming.

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COMPARATIVE FIELD STUDIES OF VARIOUS TRAPS AND ATTRACTANTS FOR THE OLIVE FRUIT FLY, *Bactrocera oleae* IN THE BALEARIC ISLANDS

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Abstract

Based on the results obtained during the previous years in the FAO and IAEA Research Coordination Project (CRP), a standard research protocol for *Bactrocera oleae* was used in the Balearics in order to test different colours of traps and different attractants based on ammonium substances.

The experiment was conducted from September to November 2004, in an organic olive orchard located in the Centre of Mallorca (Balearic Islands). The traps and attractants used were:

- A. Multilure (MLT) (yellow base) baited with hydrolysed protein
- B. MLT (yellow base) baited with Torula Yeast
- C. MLT (yellow base) baited with Ammonium Bicarbonate (AB) plus water
- D. MLT (red base) baited with hydrolysed protein
- E. MLT (red base) baited with Torula Yeast
- F. MLT (red base) baited with AB plus water

Results obtained showed that the MLT trap with yellow base, baited with hydrolysed protein attracted higher numbers of *B. oleae* males, meanwhile the same trap baited with Torula Yeast attracted higher numbers of female flies. On the other hand, MLT (red and yellow base) baited with AB attracted lower numbers of both male and female flies. No significant differences were observed between MLT with red base baited with hydrolysed protein or Torula Yeast. Regarding the proportion of males and females captured by each treatment, in general the red colour has demonstrated to be more selective for *B. oleae* females than yellow colour. Thus red colour based traps could be useful for monitoring *B. oleae* in future SIT programmes as well as a good option when considering control strategies as the mass trapping. Our results suggests that Torula Yeast could be used as attractant for *B. oleae* at the same level as the hydrolysed protein and should be tested against the Ammoniun Biphosphate, which is the attractant traditionally used in Spain for olive fruit fly monitoring.

1. INTRODUCTION

The olive fly *Bactrocera oleae* (Gmelin) is one of the major pests of olive crops in the Mediterranean Basin where 98% of world's olive oil is produced. The females lay eggs on the olives, where larvae develop and cause a premature drop of the fruits. Despite the losses in production, larvae inside the drupes also decrease the quality of the produced oil, mainly increasing acidity and reducing oil content in the fruits [1]. Traditionally olive crops have been treated with insecticides combined with a bait (hydrolized protein) in order to suppress olive fly populations [2]. These treatments are highly expensive and not selective enough as the bait used is a non-specific attractant. Furthermore, their application in extensive areas, frequently using airplanes, cause problems with secondary pests due to the reductions of populations of natural enemies [3] [4] and accumulation of insecticide residues in fruit and in the environment. In the past 10 years, public concern about pesticide residues in food has been increasing, as well as the surface of land dedicated to organic olive oil production.

For many years, olive fly in Spain has been surveyed using traditional methods based on traps baited with ammonium salts as for example the Ammonium Biphosphate. In the past 5 years (since 2000), the FAO and IAEA has funded a Co-ordinated Research Project (CRP) for development of female biased and more selective attractants for different fruit fly species. It was clear from the very beginning, that a great effort was necessary to improve the current *B. oleae* attractants, in order to reach the same level as with other species as, for example, the Mediterranean fruit fly (*Ceratitis capitata*, Wied.) [5]. Effective and low cost attractants are necessary for developing and implementing new surveillance and control techniques such as bait stations and ground and aerial bait sprays.

2. MATERIAL AND METHODS

2.1. Description of site

The experiment was conducted in an organic farming olive groove located in the municipality of Montuïri (30 km outside of Palma, the main town in Majorca). The orchard consisted of a 1 hectare field with 250 trees of the "arbequina" variety and was used also during the trials conducted in 2003. There were also 6 trees from the "picual" variety. Separation between trees was about 8m within rows and 10m between rows. The area were the experiments were conducted is not a traditional olive production zone, and for this reason, the field was totally isolated from other *B. oleae* hosts, including wild olive trees (*Olea europaea* var. silvestris). Grapes, fig and almond trees were the predominant cultivars near the experimental orchard.

The trial started the 29th September and ended the 9th November 2004. This period is frequently characterized by high *B. oleae* adult population in the Mediterranean Basin. Furthermore, it is also characterized by high temperatures and frequent rain.

2.2. Traps and attractants

The Multilure trap (MLT; Better World. Inc.) was the only type of trap used during the trial. The MLT trap is a McPhail type trap, very similar to the IPMT trap. For this experiment, we used MLT traps some with a yellow base and others with a red base. The attractants and retention systems used in the experiment are indicated in Table I. We tested liquid lures based on ammonium from biological origin, as for example NuLure and the Torula Yeast. On the other hand, we also included solid lures, as the Ammonium Bicarbonate (AB, Agrisense), a bait based on ammonium salts.

The traps were set up and placed on the field following a randomized completed block design, with 6 treatments (A to F) and 5 blocks. The traps were hang from 1.5m to 2m from ground level, orientated to the south-west and separated from each other by 30m. Traps within a block were checked twice a week during all the trial. After collecting the samples from the traps, these were rotated sequentially in the same block in a clockwise way. Solution from NuLure and Torula treatments were refilled with water if necessary during each sampling and totally replaced every 7 days. Solid attractant based on AB was replaced by a new one after 4 weeks of trial.

2.3. Analysis of captures

Males and females of *B. oleae* were separated from other species. Other important species as for example natural enemies, were also considered.

Data were standardized by transforming data to flies per trap per day (FTD) and analysed using a non-parametric analysis of variance by a Kruskall- Wallis Rank Test at 95 % confidence.

3. RESULTS AND DISCUSSION

A total of 959 males and 1403 females were captured, during the hole experiment. Results of FTD and relative efficacy are given in Table II. The treatments ranked as follows for the number of captured females: Yellow Torula, Red Torula, Yellow NuLure, Red NuLure, Yellow AB and Red AB. In the case of males, the best treatment was Yellow NuLure. followed by Yellow Torula, Red NuLure, Red Torula, Yellow AB and Red AB.

TABLE I. TRAPS, ATTRACTANTS AND RETENTION SYSTEMS USED IN THE *B. OLEAE* EXPERIMENT.

Treatment	Trap	Attractant	Retention System
A	MLT (yellow base)	NuLure [a]	
B	MLT (yellow base)	Torula [b] Yeast	
C	MLT (yellow base)	AB	Water/Triton
D	MLT (red base)	NuLure [a]	
E	MLT (red base)	Torula [b] Yeast	
F	MLT (red base)	AB	Water/Triton

[a]An aqueous solution of 300 ml of NuLure 9% plus Borax 3% was deployed in each trap.
[b]Three tablets of Torula per 300 ml water. Borax is already included in the tablets.

The treatments based in Torula either red or yellow base has demonstrated to be at the same level of efficacy compared with those treatments based in NuLure. There was no statistical difference between the amount of females captured by NuLure and Torula both with the yellow base. NuLure has been described recently as the best attractant for *B. olae* in the Balearic Islands [6] and mainland Spain [7]. It was also cited previously by other authors in Crete, where 2% hydrolysed protein solution was considered to be more efficient than ammonium salts [1].

Our results from the present work confirm that the concentration of ammonia derived from hydrolysed proteins and Torula are more attractive for *B. oleae* that the ammonia emitted by the AB placed inside traps. This attractant captured a very low number of flies, either combined with yellow or red base traps. This result was also found by other authors in Spain [6] [7]. Moreover, NuLure appeared to be more efficient when compared with the traditional Biammonium Phosphate in a 4% solution [6] [7]. On the contrary, results from work carried in the Kornati Islands (Yugoslavia) during years 1980 and 1983 [8], confirmed that Biammonium Phosphate 4% was more effective for capturing *B. oleae* than Ammonium Bicarbonate liquid solution 2% and hydrolized protein Buminal 2% solution. Considering all the information, it seems that probably the rate of ammonia emission from the solid AB dispenser is no effective when is placed inside traps, since the AB tablet was designed to be used as a “Kill and Lure” device that is totally open to the air.

Regarding the visual stimuli, yellow chromotropic traps have been used for adult *B. oleae* monitoring [9] [10], but in general they are not useful for controlling the olive fly, because of problems with the trap capturing a large number of non-target insects. Furthermore, the yellow colour used in the traps can attract other insects in high numbers, some of which are natural enemies of other pests. In fact, some authors [4] used yellow traps for estimating the olive-grove entomofauna in Italy, thus capturing a large number of insects (29,147 insects) from which 10 % were parasitoids from the *MicrohymenoPTera* group. Other authors [7] suggested also that yellow panels are not effective either baited with male pheromone or AB tablet, specially when compared with NuLure.

On the other hand, it is recognized that colour plays an important role in fruit fly host identification. The preferred colour by most of the fruit flies seems to be yellow [11], then, when visual and olfactory stimuli are combined, the captures usually increase. Our results indicate that yellow or red colours combined with NuLure or Torula attractants are proper combinations for capturing high numbers of *B. oleae* both males and females.

Regarding the proportion of males and females captured by each treatment, in general the red colour has demonstrated to be more selective for *B. oleae* females than yellow colour (Table II). In fact, both Torula and NuLure with red base showed better results regarding percentage of females captured (72.2 % and 64.5%, respectively), compared with those obtained by the same baits with a yellow base. The results obtained by NuLure with yellow base are similar to those obtained in previous trials conducted in Spain [6] [7] and showed a similar attraction both for female and males.

The high selectivity showed by the red colour indicate that red colour based traps could be useful for monitoring *B. oleae* in future SIT programmes as well as a good option when considering control strategies as the mass trapping.

On the other hand, when considering attraction for other groups of insects (Table II), the olfactory stimuli and not the colour, seems to play the most important role. In fact, Torula treatments have significantly captured more non- targeted insects, about three times more than NuLure and four times more than AB treatments. The main groups captured were specially Diptera from the Muscidae and Calliphoridae families. It seems that is necessary to test if treatments based on Torula have an important impact on natural enemy populations. Negative effect of high captures of non-targeted insects by liquid protein hydrolysates during trap servicing and fruit fly identification has been reported in the Balearic Islands in Spain [12].

TABLE II. *BACTROCERA OLEAE* MALES AND FEMALES FTD, PERCENTAGE CAPTURED BY EACH TREATMENT AND MEAN NON-TARGETED INSECTS PER TRAP PER DAY (ITD) IN EACH TREATMENT.

Treatment	Males FTD[1]	Females FTD[1]	% males	% females	ITD [1]
A	1,42 a	1,46 a	49,3	50,7	1,48 b
B	1,31 a	1,95 a	40,2	59,9	5,69 a
C	0,32 b	0,37 b	44,4	53,6	1,40 b
D	0,65 b	1,19 ab	59,2	64,5	1,75 b
E	0,63 b	1,65 a	53,1	72,2	6,24 a
F	0,01 c	0,02 c	44,3	55,0	0,21 c

[1]Values followed by the same letter do not differ significantly. (Kruskall- Wallis Test. P> 0.05)

In Spain, the most common attractant used for monitoring *B. oleae* populations is based in Ammonium Biphosphate in a 4% solution, which frequently is placed in plastic McPhail type traps or in transparent PVC mineral water bottle traps (Olipe trap). Previous results obtained from CRP trials indicated that probably NuLure was more efficient for capturing females [6] [7]. Now, our results indicate that Torula could be also considered a efficient attractant, and consequently, should be also tested against Biammonium Phosphate.

Although liquid ammonium attractants such as NuLure and Torula have demonstrated a good performance in the field, it is still necessary to increase our research effort in developing more solid lures for *B. oleae* similar to those already developed for the medfly. The organic pesticide-free olive oil production is a growing market that needs cost-effective products for surveillance and control of the olive fly, one of the major pests.

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DEVELOPMENT OF TRAPS AND KILLING AGENTS TO IMPROVE THE MASS TRAPPING TECHNIQUE AGAINST *Ceratitis capitata* WIED AND *Bactrocera oleae* GMEL. (DIPTERA: TEPHRITIDAE)

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Abstract

Under the framework of a Joint FAO/IAEA Division Co-ordinated Research Project (CRP) a number of countries have carried out experiments specially in the application of the various trapping methodologies to survey fruit flies of economic importance. Spain collaborated through an "Agreement Contract" between 2000-2005. Spain is world's number one citrus exporter to the European Community and other countries such as USA, Korea, and Japan. Nowadays "Mass Trapping" is an important activity to control medfly (*Ceratitis capitata*, Wied) in citrus areas. Thousands of traps have been hung in citrus plantations and in isolated trees (figs), all managed and coordinated by the agricultural authorities. One of the highest costs of this technique is the manpower required to bait and place the traps. Under the standard research protocol of the CRP we have developed a trap in order to facilitate the manipulation of the attractants and hanging the traps on the trees. "Easy Trap" is the name of the new trap. It is composed of a transparent and a yellow part. When assembled a rectangular box is formed. It has two invaginated opposite holes on the upper part. An adaPTable hanger allows traps to be easily and quickly hang on the fruit trees. Mass trapping experiments were conducted for control of medfly as well as for olive fly (*Bactrocera oleae*). This paper presents the results of the experiments carried out in Spain during the last year (2004) with this trap. The Easy trap baited with Ammonium Acetate and Trimethylamine using Deltamethrine as killing agent was the best trap against *C. capitata* in a mango orchard. The same trap baited with NuLure 9% + borax 3% solution was the best trap when it was tested in an olive grove against *B. oleae*.

1. INTRODUCTION

Numerous Co-ordinated Research Projects have been carried out in the last years by the Joint FAO/IAEA Division aimed at improving current fruit fly surveillance and control techniques [1]–[6]. Since the 1970's, Spain has participated in some of the CRP's and a considerable number of scientific publications have been produced contributing to the advances in this field. [7]–[14].

A new CRP began in 2000 and finished in 2005 named "Development of Improved Attractants and Their Integration into Fruit Fly SIT Management Programmes". A standard research protocol agreed by the participating scientists was followed. Within the protocol, one treatment was called "optional" giving the opportunity to the scientists to test other promising trapping systems. The new Easy trap was included in the experiment as an optional treatment. Apart from the standard protocol, participants also conducted so called "side experiments" to test other trapping systems of interest or to test specific critical variables related to trapping systems.

Preliminary bioassays of the performance of this trap were conducted in 2003 with successful results which were presented in a poster in the 5th Meeting of the Working Group on Fruit Flies of the Western Hemisphere held in Ft Lauderdale, Florida, USA (May 2004) [15].

This paper presents the findings obtained in a side experiment which compares the trap selected as standard for the experiment (i.e. Multilure trap (MTL)) against the Easy trap as described below.

2. MATERIALS AND METHODS

The Multilure Trap (MLT) baited with different food baits and retention systems was compared against the Easy trap baited with the same baits and retention systems excePT for the water/triton. Tables I and II show the different treatments used in the bioassays against medfly (*Ceratitis capitata*, Wied) and olive fly (*Bactrocera oleae,* Gmel.).

TABLE I. TREATMENTS TESTED AGAINST MEDFLY.

Treatment	Trap	Bait	Retention
1	MLT	NuLure 9%+ Borax 3%	solution
2	MLT	AA + TMA	water/triton
3	MLT	AA + TMA	DDVP
4	MLT	AA + TMA	Deltamethrine
5	Easy	AA + TMA	DDVP
6	Easy	AA + TMA	Deltamethrine
7	Easy	NuLure 9%+Borax 3%	solution

Medfly field experiments were carried out in a mango orchard sited in Malaga, south of Spain, 3 randomized blocks of different treatments (traps and attractants) were selected. The experiments were conducted in September/October when warm weather conditions prevail and medfly population are high and in October/November when colder weather prevail and populations are low.

Twice a week the traps were checked and fly catches recorded and attractants and retention systems replenished when needed. Liquid retention system and bait were renovated each week. Males and females were counted every check and traps were rotated. Nine weeks was the duration of trials, 33 days on the warm period and 31 days on the cold period.

Due to the different climatic conditions in the course of the experiment that made the medfly population variable, data were separated and, an analysis of variance was conducted for each set of data. One for high populations during the warm weather and the other for low population during the cold weather

The statistical analysis of variance ANOVA (SAS Institute, INC) was done. Before ANOVA data were transformed to ln(x+1) to reduce heterogeneity of variances.

In the case of *B. oleae* the Easy trap was tested against the MLT, both baited with the conventional NuLure 9%+ Borax 3% bait.

TABLE II. TREATMENTS TESTED AGAINST OLIVE FLY.

Treatment	Trap	Bait	Retention
1	MLT	NuLure 9%+ Borax 3%	solution
2	Easy	NuLure 9%+ Borax 3%	solution

Four blocks with the treatments shown in the table were distributed in an olives plantation of ca. 4 has in the village of Villarejo (30 Km from Madrid). Traps of the same block were separated by 15 m. The distance between blocks was 21 m.

Twice a week the traps were checked and fly catches recorded. Liquid attractants and retention systems were renovated each week. Males and females were counted every check and traps were rotated. The experiment was carried out from 1st of September to 1st of November 2004.

As in the previous bioassay, before applying ANOVA, data were transformed to ln(x+1) to reduce heterogeneity of variances.

3. RESULTS

Table III and FIG. 1 shows the medfly Captures during the warm and the cold periods. Clearly the best treatments during the warm period were the MLT and Easy traps baited with NuLure and borax with no statistical difference among them. During the cold period the best were the Easy trap baited with the synthetic food attractant (AA + TMA) and with the Delthamethrine (DM) as killing agent followed by the Easy trap baited with NuLure and borax. Interesting to note that during low populations the synthetic food lures perform better than the more generic liquid protein baits. In all cases the treatments captured a larger proportion of females than males.

The mean percentage of females captured in traps was 68.3% (synthetic food attractants with water/Triton), 66.5% (NuLure+Borax), 64.5% (synthetic food attractants with DM) and 63.2% (synthetic food attractants with DDVP).

The traps baited with synthetic food attractants using DM as killing agent, captured more flies in both warm and cold climate. It is evidence that DDVP acts like a repellent of flies.

TABLE III. NUMBER OF MEDFLIES PER TRAP PER DAY (FTD) AND PERCENTAGE (%) FEMALES CAPTURED BY EACH TREATMENT IN A MANGO ORCHARD IN MALAGA, SPAIN, 2004.

			Warm period		Cold period	
Treat/Trap	Bait	Retention	F/T/D*	% Females	F/T/D*	% Females
1/MLT	NuLure/Borax	solution	6a	59	2.3c	58.5
2/MLT	AA+TMA	water/triton	2.8bc	66.8	1.9de	70.1
3/MLT	AA+TMA	DDVP	1.3e	54.3	0.9ef	68.2
4/MLT	AA+TMA	DM	2.2cd	60.1	2.0cd	67.2
5/Easy	AA+TMA	DDVP	1.6de	54.8	3.1b	63.5
6/Easy	AA+TMA	DM	3.9b	65.8	5.3a	64.8
7/Easy	NuLure/Borax	solution	5.7a	70.7	3.5ab	77.6

*Number followed by the same letter are not statistically different (a<0.05) Duncan test

Table IV shows the olive fly Captures. Clearly in this case the best treatment was the Easy trap baited with NuLure and borax. There was no effect of the bait on the proportion of males and females captured.

TABLE IV. NUMBER OF OLIVE FLIES PER TRAP PER DAY (FTD) AND PERCENTAGE (%) FEMALES CAPTURED BY EACH TREATMENT IN AN OLIVE ORCHARD, MADRID, SPAIN, 2004.

Treat/Trap	Bait	Retention	F/T/D%	Females
1/PMT	NuLure/Borax	solution	14.3b	46.8
7/Easy	NuLure/Borax	solution	25.9a	46.2

*Number followed by the same letter are not statistically different (a<0.05) Duncan test

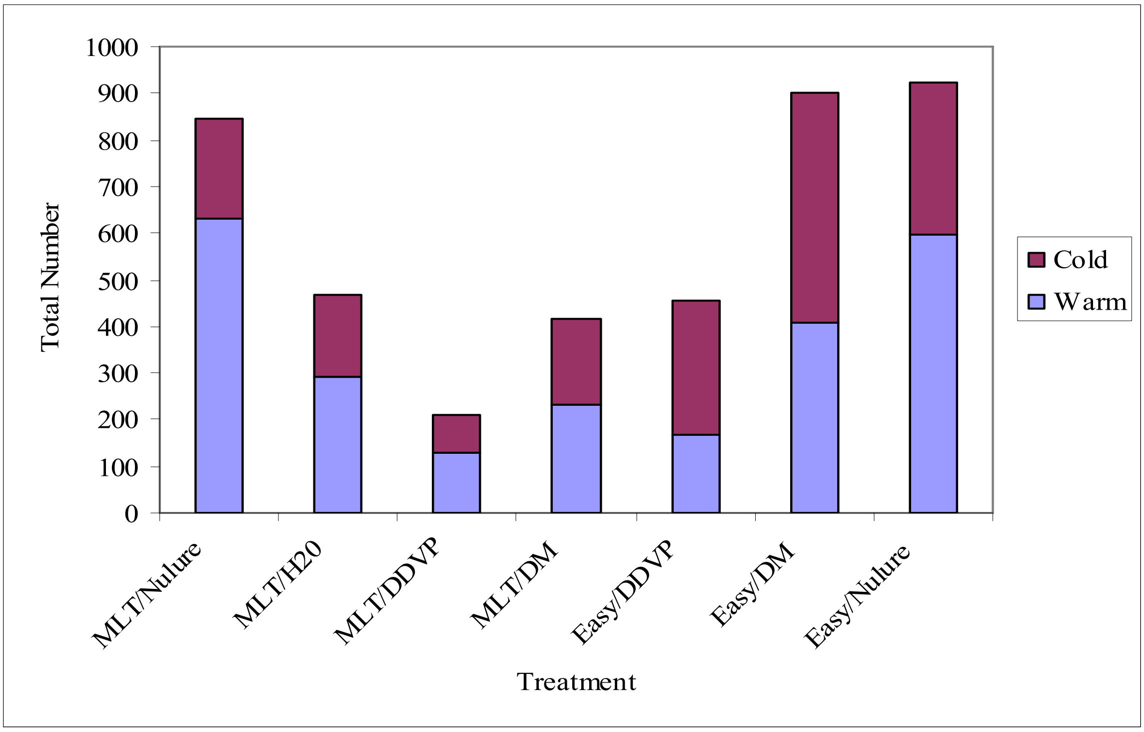

FIG 1. Total medfly Captures obtained by each treatment in a mango orchard site in Malaga, Spain, 2004.

4. CONCLUSIONS

Under the conditions prevailing in Malaga, the easy trap baited with NuLure or with the synthetic food attractant AA + TMA, is more efficient for catching medfly than the MLT baited with the same attractants thus a better option for mass trapping.

It was confirmed that at lower populations in colder climate the synthetic food attractants perform better that the conventional hydrolysed proteins.

The DM should be used as a killing agent in dry traps such as the Easy and MLT traps as the DDVP has a repellent action on flies approaching the traps.
Both the hydrolysed protein NuLure and the dry synthetic food lure tend to catch more females than males and no statistical difference was observed between these two attractants.

Under the conditions prevailing in Madrid, the easy trap baited with NuLure and borax is more efficient for catching olive fly than the MLT baited with NuLure.

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FIELD EVALUATION OF TRAP TYPES AND LURES FOR *Bactrocera oleae* (DIPTERA: TEPHRITIDAE). EXPERIMENTS CONDUCTED IN CHIOS, GREECE

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Abstract

Field experiments were conducted in Chios Greece, during the summers of 2001 to 2004 to compare different trapping systems for the olive fruit fly, *Bactrocera oleae* (Rossi). Plastic Multilure traps (MLT) (McPhail type) baited with an aqueous solution of NuLure plus borax was the most effective trapping system followed by same traps baited with Ammonium Bicarbonate (AB) tablets. Interestingly, the superiority of NuLure was persistent under low and high population densities. NuLure-baited traps were the least selective capturing large number of non-target insects. Interestingly though, they caPTure less *Chrysopids* than AB baited traps. Addition of a dispenser of the sex pheromone Spiroketol (SK) in AB-baited traps did not increase Captures of males neither the total number of adults captured. Wet (provide with water plus triton) AB-baited traps were more effective than similarly baited dry traps (provided with a DDVP tablet). Captures of olive fruit flies in a *Citrus* orchard in the same area showed that NuLure-baited MLT traps were more effective than similar traps baited with long lasting dispensers of Ammonium Acetate (AA), Putrescine (PT) and Trimethylamine (TMA). Increasing the number of AB dispensers did not result in any increase of the captured olive fruit flies. In other experiments we found that NuLure-baited, MLT traps were ≈ 2.5 times more effective than Elcophon traps baited with Entomela (a commercial Greek trap). Sensus traps baited with Questlure (a South African trap) were completely ineffective for olive fruit fly. Different combinations of AB with one or all of the following food attractant AA, PT and TMA did not increase the effectiveness of the MLT traps. Finally, we found out that changing the color of the lower part of the MLT traps from yellow to red decreased the number of the attracted olive fruit flies. The importance of these findings for developing new attractants and/or trapping systems for the olive fruit fly, as well as for the development of effective lure and kill methods for this fly is discussed.

Key Words: *Bactrocera oleae*, trapping, food attractants

1. INTRODUCTION

The olive fruit fly, *Bactrocera oleae* (Rossi) (DiPTera: Tephritidae) consists one of the most important pest for the olive production in the Mediterranean countries (7, 9). In Greece is considered as the most important agricultural pest (1, 2). There has been a considerable amount of research in developing effective sampling and control methods for this pest (1, 3, 6, 10, 15). Nevertheless, until now there is no powerful trapping system suitable for employment in mass trapping control method against this pest.

Glass McPhail traps baited with aqueous solutions of either protein hydrolysates or ammonium salts has been the most effective and extensively used system for population monitoring of *B. oleae*. Visual traps, usually sticky, yellow colored objects, alone or in combination with food attractants has also been tested for population monitoring and control purposes (4, 10, 15). The identification, chemical characterization and synthesis of the sex pheromone stimulated more research in developing pheromone based trapping systems (8). Combination of food and visual attractants with sex pheromone has been also tested (1). There are several disadvantages associated with most of the trapping systems used for the olive fruit fly today. For example, glass McPhail traps baited with aqueous solutions are fragile, their performance varies with the season and requires frequent service and renewal of the attractive solution; a labor intensive and costly process. On the other hand, visual color traps are less effective and less olive fruit fly selective than the McPhail traps, capturing most of the time large number of beneficial insects. Use of sex pheromone dispensers as one of the attractants increases the efficacy of traps in capturing males but not females. These traps are more effective early in the season and under low population densities. However, Captures of females are very important for calculating thresholds for control application, and also for developing lure and kill methods. Apparently, a female targeted trapping system, using long lasting synthetic attractants is highly desirable. Such a system has been recently developed for the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann). It consists of the attractants Ammonium Acetate, Putrescine and Trimethylamine loaded in long lasting, slow-releasing dispensers and placed in plastic Multilure traps (MLT) (McPhail type) (5, 13, 14). Slow release dispenser and synthetic attractants have several advantages, such as they are less weather depended, releasing attractants in a more constant rate than aqueous solutions, and lasting longer time than the aqueous solutions of either proteins or salts.

Reported herein are studies conducted in Chios, Greece, as part of research program coordinated by the International Atomic Energy Agency aiming to develop a new, effective trapping system for the olive fruit fly. Several food-based attractants as well as sex pheromone dispensers were tested in various combinations mostly in MLT traps. Commercial trapping systems have been included in some of the experiments.

2. MATERIALS AND METHODS

2.1. Field Site

All the experiments were conducted from July to September (2000 to 2004) in the island of Chios, Greece. The olive fruit fly population varied a lot from year to year during the five years of experimentation. Chios is located in the central Aegean Sea; about 10 km off the west coast of Turkey, and has a typical Mediterranean climate. During the experimental months the weather was characterized by moderate to high temperature (23 – 31 ºC average daily), moderate humidity, slight to moderate winds usually blowing from the north, and lack of rainfall. Experimental farms located in the area of Campos approximately 1 km west of the eastern coast of the island at an altitude of 1-2 m, in the middle of a 20 km^2 area cultivated mostly with various *Citrus spp*. trees, especially mandarins (*Citrus nobilis* Lour.), oranges (*Citrus sinensis* Osbeck) and bitter oranges (*Citrus aurantium* L.). Although citrus orchards predominate in the area, there are also several olive trees mostly planted either in the margins of the citrus plantations or as separated uniform olive orchards. In the other parts of the island olive orchards predominate. More details for the experimental area are given in (12).

2.2. Experimental procedures

Most experiments were conducted in a uniform olive orchard surrounded by several citrus orchards. This olive orchard (about one hectare in size) was composed by ≈ 200 very large, 35-year-old olive trees of the variety "Kalamon". In all the following experiments the traps were hung on the trees at a height of 1.5 to 1.8m and at a distance of ≈ 15m between the lines (blocks) and ≈ 15m within blocks with all treatments randomly distributed within each block. Unless otherwise noted, traps were checked twice a week in a regular schedule. At each check the position of the traps within each block was re-randomized. Liquid lures were renewed every week, while synthetic dispensers replaced every month.

At each check we recorded the number and sex of olive fruit flies captured and in most of the experiments we recorded also the total number of non-target insects captured. Important non target insects such as *Chrysopa spp* and the *Vespula germanica* were recorded separately.

2.2.1. Experiment 1: Comparison of different attractants in Plastic Multilure traps (McPhail type)

The experiment was conducted from July 4th to August 28th 2001. Olive trees within the orchard had almost no fruits, and therefore, the olive fruit flies captured there were most probably originated from other olive trees bearing fruits, outside of that orchard. Plastic Multilure traps (MLT) (McPhail type) (INC Manufacturing, Fresno CA) were used with different attractants. Six attractants were tested after placing them in MLT traps: a) An aqueous solution of the protein NuLure (Miller Chemical and Fertilizer, Hanover, PA) 9% (vol:vol) + 3% borax (wt/vol), b) An Ammonium Bicarbonate dispenser (AB) (AgriSence Fresno CA) + 300 ml of water and 2 drops (0.01%) of the surfactant Triton (Triton ex-100, Union Carbide, Danbury, Connecticut, USA) c) AB in a dry trap provided with a small plug (2x10x10 mm) of the insecticide DDVP (Hercon Laboratories Corp., South Plainfield, NJ) to kill flies, d) AB + a Spiraketol (SK) pheromone dispenser (AgriSence Fresno CA) +water/Triton (as in b), e) An aqueous solution of Ammonium Phosphate (AP) 3% company + Triton, f) An Ammonium Acetate dispenser (AA, (BioLure, Consep, Bend, OR)) + water/Triton.

There were 5 blocks of 6 trap-treatments each checked two times per week. After each trap check treatments were re-randomized within blocks.

2.2.2. Experiment 2: Trapping olive flies in McPhail traps placed in a Citrus orchard

At the same time with the above experiment we run a similar experiment in citrus orchards testing trapping systems for *Ceratitis capitata* (Wiedemann). Since there were many olive fruit flies captured in the citrus orchard where different food attractants were used we present here the results concerning captures of the olive fruit fly. Citrus orchard was composed of mandarin trees and the following attractants were tested in MLT traps: a) An aqueous solution of the protein NuLure 9% (vol:vol) + 3% borax (wt:vol), b) the three component BioLure (Consep, Bend, OR). dispensers (FA-3) of the compounds Ammonium Acetate (AA), Trimethylamine (TMA) and Putrescine (PT) (BioLure, Consep Inc., Bend, OR, USA) + water/Triton, c) FA-3 + water with propylene-glycol (10%) d) FA-3 + DDVP, e) FA-3 + Deltamethrine f) FA-3 + a sticky insert place in the trap in order to caPTure the attracted flies. Other experimental details were as above.

2.2.3. Experiment 3: Testing different Ammonium Bicarbonate doses

The experiment was conducted from July 7th to September 4 2002 in the olive orchard described in experiment 1. A total of 30 traps were installed in 5 blocks of 6 trap-treatments each. Each block consisted of the following six treatments of MLT traps baited with: a) 9% NuLure, 3% borax, 88% water (by weight), b) One dispenser of the lure Ammonium Bicarbonate (AB) (AgriSence tablets) with the addition of 300 ml of water and surfactant (1-2 drops) to the trap base, c) same as b above but with 2 AB dispensers, d) same as b above with 4 AB dispensers, e) same as b above but with one Ammonium Acetate (AA) dispense (Biolure), and f) Ammonium Sulphate (AS) solution (2% in water of the fertilizer 21-0-0) plus Triton.

2.2.4. Experiment 4: Comparing different combinations of synthetic food attractants

The experiment was conducted from July 14th to August 12, 2003 in the orchard described in experiment 1. A total of 30 traps were installed in 5 blocks of 6 treatments each. Each block consisted of the following six treatments of MLT baited traps: a) 9% NuLure, 3% borax, 88% water (by weight), b) One dispenser of Ammonium Bicarbonate (AB) (Agrisense tablets) with the addition of 300 ml of water and surfactant (1 drop of 10% Triton in one liter water) to the trap base, c) same as b above with the addition of an AA dispensers, d) same as b above with the addition of one TMA dispensers, e) same as b above with but with one Putrescine (PT) dispenser, f) same as b above with the addition of all three dispensers (AA, TMA, PT; FA-3).

NuLure bait and water/Triton were renewed weekly but AB and the other dispensers remained the same throughout the experiment.

2.2.5. Experiment 5: Testing different local proteins against NuLure in Plastic Multilure traps

The experiment was conducted from 23 to 30 August 2003 in the same olive orchard where the previous experiments were conducted, and following the same methodology. The following treatments were tested in MLT traps: a) NuLure (9%) + borax (3%) in 88% water, b) The local protein "Entomela" (9%) + borax (3%) in 88% water, c) the local protein lure "Dacus bait" (9%) + borax (3%) in 88% water, d) The local protein lure "Alma Dacus" (9%) + borax (3%) in 88% water. ExcePT NuLure, the other proteins are used in Greece as a lure in the bait sprays applied against the olive fruit fly. There were 4 treatments of 5 replicates each, serviced 2 times.

2.2.6. Experiment 6: Comparing NuLure and Ammonium Bicarbonate (AB) in Plastic Multilure traps (McPhail type) of different colour against red spheres baited with AB

This experiment was conducted from 24 August to 6 September 2004. The following treatments were tested following a complete randomized blocks experimental design (5 blocks of 5 treatments each, serviced 6 times): a) MLT (yellow base) + NuLure + borax, b) MLT (yellow base) + AB + Water/Triton, c) MLT (red base – painted) + AB + water/triton, d) MLT (red base new – manufactured) + AB + Water/Triton, e) Sticky Red Sphere + AB.

2.3. Statistical Analysis

The total number of flies captured throughout the experimental period was submitted to ANOVA and analyzed as a randomized complete block design. Before ANOVA data were transformed to ln(x+1) to reduce heterogeneity of variances, but untransformed means are given in the tables (Sokal and Rohlf 1995). Means were separated using Tukey's HSD test.

3. RESULTS AND DISCUSSION

3.1. Experiment 1: Comparison of different attractants in MLT traps

The mean numbers of olive fruit flies, and other insects captured during the entire experimental period in the olive orchard are given in Table I. The most effective trap for both sexes of *B. oleae* was the NuLure baited trap followed by the wet Ammonium Bicarbonate (AB) baited and AB plus Spiroketal (SK) baited traps. Ammonium Bicarbonate baited traps in which a SK pheromone dispenser was added, did not differ in effectiveness from the AB baited ones, neither for males nor for females. However, it was significantly more effective than Ammonium Acetate baited traps and dry traps baited with AB. Traps baited with Ammonium Phosphate (AP) captured a very small number of olive fruit flies. NuLure-baited traps were the most effective trapping system throughout the experimental period. Almost all treatments captured 2-3 times more males than females. Traps baited with NuLure captured more non-target insects (including several *C. capitata*) than the other treatments. However, they were capturing less chrysopids than AB and AB+SK baited traps (Table II).

The results render NuLure as the most powerful attractant. Ammonium Bicarbonate which followed was more effective when used in wet traps. It seems that wet traps are more effective than dry ones. The synthetic sex pheromone was not effective at all, since combination of this attractant with AB did not increase the captures of neither males nor females.

3.2. Experiment 2: Trapping olive flies in MLT traps placed in a *Citrus* orchard

Captures of olive fruit fly adults in a citrus orchard were significantly higher in NuLure baited PMT traps, followed by the two treatments of wet traps baited with FA-3 (Table III). Similar to the previous experiment more males than females were captures in almost all the traps. The higher efficacy of the NuLure baited traps persisted throughout the experimental period (data not shown). These results highlight the superiority of wet traps and show that the combination of the three synthetic attractants (FA-3) is not effective for the olive fruit fly.

TABLE I. *BACTROCERA OLEAE* ADULT CAPTURES IN MLT TYPE TRAPS PLACED IN AN OLIVE ORCHARD DURING JULY AND AUGUST 2001 IN CHIOS.

Treatments	Mean no. per trap (±SE)		
	Males	Females	Other insects
NuLure	248.4 ± 33.8a	110.0 ± 18.7a	1237.0 ± 176.1a
AB + (water, triton)	142.2 ± 30.4b	61.6 ± 14.2ab	139.6 ± 31.6b
AB + DDVP	23.2 ± 9.8d	7.4 ± 2.6c	9.6 ± 3.8d
AB + SP + (water, triton)	131.2 ± 33.7b	52.2 ± 11.7ab	125.8 ± 36.0b
AP + (water, triton)	3.4 ± 1.5e	4.8 ± 2.2c	44.0 ± 6.3c
AA + (water, triton)	61.6 ± 10.0c	27.0 ± 4.0b	126.8 ± 22.8b
F	83.9	41.2	172.3
(df = 5, 20; *P* < 0.01)			

Means followed by the same letters in the same column are not significantly different ($P < 0.05$, Tukey's HSD). Before analyses data were transformed to Ln(x) but in the table untransformed values are given. [a] Including *C. capitata* adults.

TABLE II. CHRYSOPIDAE AND OTHER INSECT (EXCLUDING *C. CAPITATA*) CAPTURES IN MLT TYPE TRAPS PLACED IN AN OLIVE ORCHARD DURING JULY AND AUGUST 2001 IN CHIOS.

Treatments	Mean no. per trap (±SE)		
	Chrysopa spp	Other insects	Total
NuLure	16.2 ± 1.6b	941.0 ± 121.1a	957.2 ± 121.7a
AB + (water, triton)	28.4 ± 1.6a	38.2 ± 4.9b	66.6 ± 5.2b
AB + DDVP	1.4 ± 0.5d	5.2 ± 1.9c	6.6 ± 1.7d
AB + SP + (water, triton)	32.2 ± 1.9a	38.8 ± 4.2b	71.0 ± 5.1b
AP + (water, triton)	8.6 ± 0.8c	24.0 ± 3.2b	32.6 ± 3.1c
AA + (water, triton)	9.0 ± 1.0c	34.0 ± 2.8b	43.0 ± 2.7c
F	86.9	148.7	198.5
(df = 5, 20; *P* < 0.01)			

Means followed by the same letters in the same column are not significantly different ($P < 0.05$, Tukey's HSD). Before analyses data were transformed to Ln(x +1) but in the table untransformed values are given.

3.3. Experiment 3: Testing different Ammonium Bicarbonate doses

Mean numbers of olive fruit flies and other insects captured by the different trap treatments tested are given in Table IV. These results show that the most effective trap for both sexes (males and females) was that baited with NuLure. NuLure baited traps were the most effective for male, whereas for females the NuLure baited traps were equally effective with traps baited with AB dispensers. Traps baited with one, two or four AB dispensers were equally effective, and those baited with AA and AS were the least effective. As far as selectivity concerned, the NuLure baited traps were the less selective from all other treatments, which were more or less equally selective. However, the numbers of beneficial chrysopids captured in NuLure baited traps was similar to the numbers captured by the other treatments (in avg. 5.4, 6.8, 5.0, 3.0, 2.0 and 3.8 chrysopids by NuLure, 1 AB, 2AB, 4AB, AA and AS treatments respectively).

Although the rate of ammonia release was not measured in this experiment, the acquired data show no dose depended response of the olive fruit flies to AB lures. Sex ratio of the captured flies was always in favor of males. Different doses of AB seem to influence the sex ratio of the captured flies.

TABLE III. *BACTROCERA OLEAE* ADULT CAPTURES IN MLT TYPE TRAPS PLACED IN A CITRUS ORCHARD DURING JULY AND AUGUST 2001 IN CHIOS.

Treatments	Mean no. per trap (±SE)		
	Males	Females	Total
NuLure + borax	172.0 ± 35.2a	58.8 ± 9.5a	230.8 ± 44.3a
FA-3 + (water, triton)	32.0 ± 7.1b	14.6 ± 2.2b	46.6 ± 8.8b
FA-3 + (water, propylene-glycol)	27.2 ± 2.1b	12.6 ± 3.1b	39.8 ± 5.0b
FA-3 + DDVP	4.2 ± 0.3c	1.6 ± 0.7c	5.8 ± 0.9c
FA-3 + Deltamethrine	2.0 ± 0.5c	1.6 ± 0.2c	3.6 ± 0.7c
FA-3 + Sticky insert	3.0 ± 0.8c	4.2 ± 1.6c	7.2 ± 2.4c
F	63.2	27.0	50.8
(df = 5, 20; *P* < 0.01)			

Means followed by the same letters in the same column are not significantly different (*P* < 0.05, Tukey's HSD). Before analyses data were transformed to Ln(x +1) but in the table untransformed values are given.

TABLE IV. *BACTROCERA OLEAE* (B.O.) AND OTHER INSECT CAPTURES IN MLT TRAPS OF DIFFERENT TREATMENTS, PLACED IN AN OLIVE ORCHARD 2002.

Treatments	**Mean no. per trap (±SE)**		
	***B.o.* Males**	***B.o.* Females**	**Other insects**
NuLure + Borax	28.2 ± 4.7a	10.8 ± 2.5ab	1646.0 ± 420.3a
AB + Water, triton	14.6 ± 4.4bc	11.2 ± 4.1a	218.0 ± 58.0b
2AB + Water, triton	16.6 ± 5.9bc	7.2 ± 1.8ab	145.0 ± 29.2b
4AB + Water, triton	18.8 ± 8.0b	11.2 ± 3.6a	111.3 ± 35.3b
AA + Water, triton	8.2 ± 2.8c	4.8 ± 1.4ab	248.6 ± 69.7b
AS + Water, triton	16.2 ± 5.2bc	6.2 ± 1.9b	133.0 ± 30.0b
F	9.5	3.15	15.3
(df = 5, 20; *P* < 0.05)			

Means followed by the same letters in the same column are not significantly different (*P* < 0.05, Tukey's HSD). Before analyses data were transformed to Ln(x) but in the table untransformed values are given.

3.4. Experiment 4: Comparing different combinations of synthetic food attractants

The results of the coordinated experiment are given in Table V. NuLure was the most effective of the treatments tested for both sexes, capturing 4 times more males than females. Traps baited with one Ammonium Bicarbonate (AB) dispenser plus PT were the second more effective, followed by those traps baited with one AB dispenser. Traps baited with combinations of AB with AA or TMA as well as traps baited with AB and all the three food attractants (AA, PT and TMA) were the least effective. The results suggest a possible additive effect of AB and PT.

TABLE V. CAPTURES OF OLIVE FRUIT FLIES IN MLT TRAPS OF DIFFERENT TREATMENTS 2003.

Treatments	**Mean no. per trap (±SE)**	
	Males	**Females**
NuLure	27.9 ± 4.6a	8.9 ± 1.4a
AB	8.6 ± 1.5bc	2.8 ± 0.5bc
AB + AA	6.7 ± 1.0bc	2.3 ± 0.4bc
AB + TMA	5.2 ± 0.9c	1.9 ± 0.3bc
AB + PT	12.2 ± 2.7b	3.9 ± 0.6bc
AB + FA-3	4.0 ± 0.7c	1.6 ± 0.4c
F	15.6	13.9
df	5, 230	5, 230
P	<0.001	<0.001

Means followed by the same letters in the same column are not significantly different (P < 0.05, Tukey's HSD).

3.5. Experiment 5. Comparison of different proteins as baits in plastic Multilure trap (McPhail type)

The results of this experiment (Table VI) show that NuLure was 3-5 times more effective for both sexes than each of the other three local proteins tested (Entomela, Dacus bait and Alma Dacus), among which there were no differences. All treatments captured more males than females.

3.6. Experiment 6: Effect of colour on the attractiveness of AB baited MLT traps

The results of this experiment confirm the fact that NuLure baited standard (with yellow base) MLT traps were the most effective both for male and female olive fruit flies. Same traps baited with AB and water plus triton were much more effective than similarly baited traps that have red colored bases. It seems that the red color of the base of the trap was rather repellent to flies. However, sticky red spheres baited with AB as well were as much effective as the similarly baited MLT traps with the standard yellow base. Obviously the shape of the object besides color plays an important role in the attractiveness of the olive fruit flies to ammonia releasing baits (10, 11).

4. CONCLUSIONS

Our results show that NuLure was the most effective of the attractants tested in all the experiments conducted. NuLure outperforms other protein baits as well as ammonium salts and synthetic attractants. The superiority of NuLure is in accordance with previous findings (Katsoyannos unpublished). However, it was rather surprising that other commercial products designed for olive fruit fly, especially the combination of AB with SK were not very effective. Interestingly, the superiority of NuLure was persistent under low and high population densities.

In general wet traps were more effective than dry ones. This tendency is clear when wet and dry traps baited with AB were compared. We can therefore conclude that under the climatic particularities of the experimental area (dry, hot conditions) wet traps perform better for the olive fruit fly than dry ones. Similar results have been found for the Mediterranean fruit fly in experiments conducted in the same area (13, 14).

TABLE VI. CAPTURES OF OLIVE FRUIT FLIES IN MLT TRAPS BAITED WITH DIFFERENT PROTEINS 2003.

Treatments	Mean no. per trap (±SE)	
	Males	**Females**
NuLure	102.2 ± 21.6a	51.1 ± 12.6a
Entomela	21.0 ± 3.9b	8.4 ± 2.1b
Dacus Bait	30.6 ± 5.9b	13.0 ± 2.5b
Alma Dacus	24.4 ± 3.2b	10.6 ± 1.4b
F	14.2	11.2
(df = 3, 36; $P < 0.05$)		

Means followed by the same letters in the same column are not significantly different ($P < 0.05$, Tukey's HSD).

TABLE VII. CAPTURES OF OLIVE FRUIT FLIES IN MLT TRAPS OF DIFFERENT TREATMENTS, AND DIFFERENT SPHERE TREATMENTS 2004

Treatments	Mean no. per trap (±SE)	
	Males	**Females**
PMT, NuLure	42.6 ± 15.8a	18.8 ± 4.9a
MLT, Yellow, AB, water + triton	10.8 ± 5.6b	3.2 ± 1.0b
MLT, red, AB, water + triton	0 ± 0.0c	0.4 ± 0.2bc
Sphere, sticky	7.4 ± 3.5b	1.8 ± 1.1bc
MLT, red(new), water + triton	1 ± 0.4c	1 ± 0.6c
F	14.1	12.7
df	4, 16	4, 16
P	<0.001	<0.001

Means followed by the same letters in the same column are not significantly different ($P < 0.05$, Tukey's HSD).

The effectiveness of Ammonium Bicarbonate dispensers does not increase when the dose increases. Also, combinations of synthetic food attractants mostly with AB did not result in significant increase of the effectiveness of the baited traps. The only combination that looks promising was that of AB with Putrescine. Further research towards improvement of the effectiveness of AB baited traps is obviously needed.

In a recent study (10) it was reported that 7.0 cm diameter sticky red spheres were very attractive, especially for olive fruit fly females, capturing about 3 times more females than McPhail traps baited with ammonium sulfate. More recent data show that internally AB-baited spheres perform equally well than NuLure baited MLT traps (Katsoyannos et al. unpublished). Therefore, combination of food attractants with strong visual stimuli may result in the development of a powerful lure and kill system for the olive fruit fly. Similar studies have been conducted for *C. capitata* with promising results (11).

All trapping systems and attractants tested captured more males than females. More work is needed to develop female targeted trapping systems for the olive fruit fly. From the synthetic attractants tested AB was the most promising. However, its effectiveness was almost half that of the NuLure. Future research should aim in the development of stronger and more female specific attractants.

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DEVELOPMENT AND EVALUATION OF IMPROVED MEDITERRANEAN FRUIT FLY ATTRACTANTS IN ISRAEL

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Abstract

A survey on development and evaluation of synthetic food attractants for Mediterranean fruit fly trapping, had been carried out within various plantations in Israel, throughout the years, 2001-2004. All field tests followed a standard protocol developed by the participants of Coordinated Research Project (CRP), of the FAO and IAEA Joint Programme. The research work was aimed at developing an oPTimal mass trapping system for the Mediterranean fruit fly (*Ceratitis capitata,* Wied.*)* in support of area-wide IPM programmes. Trapping experiments included combinations of different lures, traps and various retention agents. Positive results were obtained in three consecutive years, showing a significant response of medflies to a three-component synthetic food lure (AA+ PT+TMA), in McPhail type traps (Multilure Traps (MLT) and an Israeli-MLT trap design)), using DDVP or water as the retention agents. Both sexes of *C. capitata* did not respond as well to MLT traps baited with NuLure and some combinations of the synthetic food lure throughout the four year project. Likewise, relatively low captures were documented in sticky Jackson traps with AA+ PT+TMA. Similar results regarding optimal trapping system for medflies had been obtained in other countries by participants of the CRP. These trapping systems may be tested for mass trapping for medfly suppression, which is required prior to the release of sterile insects, a technique in use in Israel and in some other countries.

Key Words: Mediterranean fruit fly, medfly, *Ceratitis capitata*, food based attractants

1. INTRODUCTION

The Mediterranean fruit fly (medfly) *Ceratitis capitata (*Wiedemann)*,* is a tephritid fruit fly pest of great economic importance for its extremely wide host range [1]. As any key pest, medfly needs to be effectively controlled, however, the use of calendar spraying of broad spectrum insecticides is not sustainable in the long term because of its negative effect to the environment [2], and the high control costs [3]. Medfly can be effectively controlled through an area-wide integrated pest management approach. Among the methods used for medfly control, area-wide SIT integrated with other control methods and surveillance systems, has shown to be cost-effective [4, 5, 6]. In the last decade substantial financial resources have been invested in optimizing SIT technology. This Coordinated Research Project (CRP), of the FAO and IAEA Joint Programme has the aim of developing and evaluating female biased synthetic food attractants applied against fruit flies of economic importance for their integration into fruit fly SIT management programmes. CRP participants from countries in Africa, Asia, Latin America and Europe were separated in groups according with the dominant fruit fly species present in their countries. Israel, as other Mediterranean countries, is typically affected by *C. capitata* with considerable economic damage [7]. Since medfly management in Israel is still based on aerial bait sprays, efforts are aimed towards the development of an effective strategy for the suppression of medfly populations. Accordingly, trapping systems used for mass trapping of adult populations are considered to be a promising control alternative. Unsuccessful experience with mass trapping for suppression has been documented via the use of male annihilation technique with Methyl Eugenol, a male specific attractant used against several species of *Bactrocera* [8]. However, research focused on female-targeted trapping systems did yield encouraging results [9, 10]. Further studies in Israel, which included different trapping strategies resulted in successful medfly control [11, 12]. The current study includes a wide range of trapping systems including those that have been tested in the studies mentioned above.

2. MATERIALS AND METHODS

Studies during the years 2001 to 2003 were conducted in the northern east region of Israel. One of the sites was located in Hauula Valley, in Kibutz Dan, in a 15 year old organic persimmon orchard. Conditions of the site are: Altitude 100 meters over seal level, Avg. Temp. (Min-Max): 22°C (17°C-37°C). Avg. RH (Min-Max): 67% (37%-96%). Traps were hung on trees at 2 to 2.5m high. Since

1997, the management of medfly in the experimental persimmon orchard was based on mass trapping with MLT traps baited with the three component lure Ammonium Acetate (AA), Trimethylamine (TMA) and Putrescine (PT) (Biolure). For the experiment all traps were removed from the orchard, before placing the different treatments used in the experiment. The basic trap used in all studies was the McPhail type Multilure (MLT) trap. Attractants consisted of combinations of the synthetic food lures AA+ PT+TMA [13]. Retention materials used were: water, DDVP and sticky coating. The Israeli designed Shabtiely trap**,** was chosen as one of the optional treatments in all field tests. The experimental design used was a complete randomized block with 5 replicates. Traps were hung equidistant at a distance of 17m between treatments and 20 m between rows (blocks). Traps were checked and rotated twice a week. Dead and captured insects were counted and removed after each trap check. Other experimental sites were located around the same area described above with other various hosts as detailed bellow.

2.1. Trapping Experiments in 2001

2.1.1. Site 1

Traps were hung in a 0.5 hectare 30 year old organic plum orchard in trees at 3 to 3.5m from the ground. No chemical control was used in this site against medfly as it was located in the backyard of a small motel. In an optional treatment the AA+ PT+TMA was replaced by Trimedlure (TML) plugs, a medfly males specific para-pheromone. The experiment was conducted from 13 of June to 13 of August 2001.

TABLE I. LIST OF TREATMENTS USED IN SITE 1 IN 2001.

	Trap	Attractant	Retention
A	MLT	AA+ PT+TMA	Water
B	MLT	AA+ PT+TMA	DDVP
C	MLT	AA+ PT+TMA	Sticky
D	Israreli	AA+ PT+TMA	Water
E (optional)	MLT	TML	Water

2.1.2. Site 2

Traps were hung in the persimmon orchard described in Section 2. This experiment was an excePTion with regards to the retention materials. Two new materials were included in treatments, propylene glycol (PG), and Deltamethrine (DM). The experiment was conducted from 9 of September to 11 of November 2001.

TABLE II. LIST OF TREATMENTS USED IN SITE 2 IN 2001.

	Trap	Attractant	Retention
A	MLT	AA+ PT+TMA	Water
B	MLT	AA+ PT+TMA	DDVP
C	MLT	AA+ PT+TMA	Sticky
D	Israeli	AA+ PT+TMA	PG
E	MLT	AA+ PT+TMA	DM

2.2. Trapping Experiments in 2002

Traps were hung in the persimmon orchard described in Section 2. The experiment was conducted from 7 of October to 30 of November 2002.

TABLE III. LIST OF TREATMENTS USED IN 2002.

	Trap	Attractant	Retention
A	MLT	NuLure	
B	MLT	AA+TMA	DDVP
C	MLT	AA+ PT+TMA	DDVP
D	MLT	AA+PT	DDVP
E	MLT	AA	DDVP
F	MLT	AA+ PT+TMA	Sticky
G (optional)	Israeli	AA+ PT+TMA	DDVP

2. 3. Trapping experiments in 2003

Traps were hung in the persimmon orchard described in Section 2. Two additional optional treatments were included in this experiment, apart from the standard ones. These were a Jackson trap (JT) baited with Biolure (AA+PT+TMA) and a JT baited with AA+TMA. The experiment was conducted from 16 of September to 14 of November 2003.

TABLE IV. LIST OF TREATMENTS USED IN SITES 1 AND 2 IN 2003.

Treatment	Trap	Attractant	Retention
A	MLT	NuLure	Water
B	MLT	AA + PT +TMA	Water
C	MLT	AA + TMA	Water
D	MLT	1/2AA+TMA	Water
E	MLT	1/2AA+PT+TMA	Water
F (optional)	Israeli	AA + PT+TMA	Water
G (optional)	JT	AA + PT + TMA	Sticky
H (optional)*	JT	AA + PT	Sticky

*tested only in site 1

Data were analyzed using a multifactor analysis of variance, followed by pairwise comparisons with the LSD test.

3. RESULTS AND DISCUSSION

Results of trapping tests in 2001 that were aimed mainly at measuring the effect of various retention materials, indicate that the most efficient material was DDVP, with a total of 35.4% relative female trap efficiency (Table V). Nevertheless, fly per trap per day (FTD) values did not show any significant statistical difference among treatments using different retention materials (Table VI). The optional treatment that presented a different attractant, TML, appeared as expected with the highest Captures of male medflies (P= 0.008), but with a significant low value of females (P=0.012).

TABLE V. RELATIVE TRAP EFFICIENCY IN SITE 1, 2001.

Treatment			Relative Trap Efficiency		
Trap	Attractant	Retention	%Females	%Males	%Total
MLT	AA + PT +TMA	Water	18.0	12.8	15.5
MLT	AA + PT +TMA	DDVP	35.4	16.5	26.1
MLT	AA + PT +TMA	Sticky	25.1	8,7	17.1
Israeli MLT	AA + PT +TMA	Water	14.6	3.9	9.4
MLT	TML	Water	5.8	58.0	31.9

TABLE VI. AVERAGE NUMBER OF FLIES PER TRAP PER DAY IN SITE 1, 2001.

Treatment			FTD	
Trap	Attractant	Retention	Females	Males
MLT	AA + PT +TMA	Water	0.9±0.2 a	0.7±0.2 b
MLT	AA + PT +TMA	DDVP	1.8±0.5 a	0.9±0.2 b
MLT	AA + PT +TMA	Sticky	1.2±0.3 a	0.5±0.2 b
Israeli MLT	AA + PT +TMA	Water	0.7±0.2 a	0.2±0.0 b
MLT	TML	Water	0.3±0.1 b	3.1±1.2 a

Results in the other tests conducted in site 2, follow the same trend, showing no influence of retention materials on trapping efficacy. Although PG in Israeli trap appeared with the highest trapping efficiency (Table VII), no significant differences in FTD values were found among treatments, for both females and males (P=0.924, and P= 0.07, respectively), (Table VIII).

TABLE VII. RELATIVE TRAP EFFICIENCY IN SITE 2, 2001

Treatment			Relative Trap Efficiency		
Trap	Attractant	Retention	%Females	%Males	%Total
MLT	AA + PT +TMA	Water	17.6	12.4	15.0
MLT	AA + PT +TMA	DDVP	20.6	14.4	17.5
MLT	AA + PT +TMA	Sticky	21.2	9.3	15.3
Israeli	AA + PT +TMA	PG	27.0	39.2	33.2
MLT	AA + PT +TMA	DM	13.6	24.7	19.2

TABLE VIII. AVERAGE NUMBER OF FLIES PER TRAP PER DAY IN SITE 2, 2001

Treatment			Fly/Trap/Day	
Trap	Attractant	Retention	Females	Males
MLT	AA+ PT+TMA	Water	0.8±0.4 a	0.1±0.0
MLT	AA+ PT+TMA	DDVP	0.8±0.3 a	0.0±0.0
MLT	AA+ PT+TMA	Sticky	0.9±0.5 a	0.0±0.0
MLT	AA+ PT+TMA	PG	1.2±0.6 a	0.2±0.0
MLT	AA+ PT+TMA	DM	0.8±0.2 a	0.1±0.5

The second phase of the research project emphasized the effect of attractants on trapping efficiency, clearly showing a difference among treatments. NuLure showed the lowest total trapping efficiency value, only 1.5% (Table XIV). With regards to the FTD, NuLure was again the lowest with a significant difference compared to other treatments in female (P= 0.005) as well as in male captures (P=0.001), as shown in Table X. The highest values among all treatments was obtained by Israeli trap for both sexes, though with no significant difference, when compared to all other combinations of synthetic food lures including the AA + PT + TMA (Biolure) in a MLT trap

TABLE XIV. RELATIVE TRAP EFFICIENCY IN 2002

Treatment			Relative Trap Efficiency		
Trap	Attractant	Retention	%Females	%Males	%Total
MLT	NuLure	Water	2.3	0.8	1.5
MLT	AA+TMA	DDVP	13.3	12.8	13.1
MLT	AA+TMA+PT	DDVP	15.8	17.4	16.6
MLT	AA+PT	DDVP	15.2	13.5	14.3
MLT	AA	DDVP	15.0	13.0	14.0
MLT	AA+TMA+PT	Sticky	14.4	16.4	15.4
Israeli MLT	AA+TMA+PT	DDVP	24.0	26.2	25.1

TABLE X. AVERAGE NUMBER OF FLIES PER TRAP PER DAY IN 2002.

Treatment			Fly/Trap/Day	
Trap	Lure	Retention	Females	Males
MLT	NuLure	water	1.7±0.1 b	0.1±0.0 b
MLT	AA+TMA	DDVP	9.4±2.3 a	2.3±0.5 a
MLT	AA+TMA+PT	DDVP	11.2±3.1 a	3.1±0.6 a
MLT	AA+PT	DDVP	9.5±2.4 a	2.4±0.3 a
MLT	AA	DDVP	10.7±2.3 a	2.3±0.4 a
MLT	AA+TMA+PT	Sticky	10.7±2.9 a	2.9±0.5 a
Israeli MLT	AA+TMA+PT	DDVP	17.7±4.6 a	4.6±1.6 a

Trapping experiments in 2003, included some treatments that had been tested in previous years, in order to validate the results. Results of this experiment were consistent with what was obtained in 2002, with NuLure being the worst treatment and AA+TMA+PT the best both using the MLT trap or the Israeli trap. As shown in Table XI trap efficiency using NuLure reached only 2.3%, whereas the two other mentioned treatments showed to be the most efficient trapping systems. Results of Jackson trap did not appear with any advantages in trapping efficiency as well as the combination between MLT trap with a sticky insert (Table XII). In this case no significant differences was found between treatments in rate of Captures, despite the relatively big gaps between the most efficient systems that had an average female FTD of 6.1 and 5.9 whereas the Jackson trap baited with AA+PT+TMA and the MLT trap baited with NuLure, had an average female FTD of only 0.5 and 0.7, respectively (Table XII).

TABLE XI. RELATIVE TRAP EFFICIENCY IN SITE 1, 2003

Treatment			Relative Trap Efficiency		
Trap	Attractant	Retention	%Females	%Males	%Total
MLT	NuLure		2.4	2.2	2.3
MLT	AA + PT +TMA	Water	22.0	20.1	20.4
MLT	AA + TMA	Water	16.2	17.7	17.4
MLT	1/2AA+TMA	Water	15.1	13.7	14.0
MLT	1/2AA+PT+TMA	Water	13.2	14.1	13.9
Israeli MLT	AA + PT+TMA	Water	20.2	19.5	19.6
JT	AA + PT + TMA	Water	1.3	1.5	1.5
MLT	AA + PT	Sticky	9.6	11.2	10.9

TABLE XII. AVERAGE NUMBER OF FLIES PER TRAP PER DAY IN SITE 1, 2003.

Treatment			Fly/Trap/Day	
Trap	Lure	Retention	Females	Males
MLT	NuLure		0.7± 0.4 a	0.9±0.4
MLT	AA + PT +TMA	Water	6.1±2.5 a	1.3±0.6
MLT	AA + TMA	Water	5.4 ±2.5 a	0.2±0.1
MLT	1/2AA+TMA	Water	3.9 ±1.7 a	0.9±0.4
MLT	1/2AA+PT+TMA	Water	4.3±1.6 a	0.8±0.3
Israeli MLT	AA + PT+TMA	Water	5.9±2.7 a	1.2±0.5
JT	AA + PT + TMA	Sticky	0.5±0.2 a	0.09±0.0
MLT+JT	AA + PT		3.4 ±1.4 a	0.6±0.2

Studies in the second site generally maintained the results obtained in the first site, with certain differences. One obvious result shown in Tables XIII and XIV, is the significant difference between the efficiency of the Israeli trap and rate of female caPTure compared with all other trapping systems. FTD values presented in Table XIV show a definite statistical difference between treatments as mentioned above with a P=0.038 for females and a P=0.001 for males.

TABLE XIII. RELATIVE TRAP EFFICIENCY IN SITE 2, 2003

Treatment			Relative Trap Efficiency		
Trap	Attractant	Retention	%Males	%Females	%Total
MLT	NuLure		2.37	1.90	1.82
MLT	AA + PT +TMA	Water	17.14	14.99	15.36
MLT	AA + TMA	Water	18.29	16.00	16.40
MLT	1/2AA+TMA	Water	12.93	12.47	12.33
MLT	1/2AA+PT+TMA	Water	13.45	15.95	15.53
Israeli-MLT	AA + PT+TMA	Water	35.96	37.18	36.99
JT	AA + PT + TMA	Sticky	0.73	1.70	1.54

TABLE XIV. AVERAGE NUMBER OF FLIES PER TRAP PER DAY IN SITE 2, 2003.

Treatment			Fly/Trap/Day	
Trap	Attractant	Retention	Females	Males
MLT	NuLure		0.5±0.1 c	0.1±0.1 b
MLT	AA + PT +TMA	Water	3.7±2.1 b	1.1±0.8 b
MLT	AA + TMA	Water	4.5±1.6 b	1.1±0.3 b
MLT	1/2AA+TMA	Water	3.2±1.0 b	0.7±0.2 b
MLT	1/2AA+PT+TMA	Water	3.2±1.2 b	0.5±0.1 b
Israeli MLT	AA + PT+TMA	Water	7.4±2.4 a	1.6±0.4 a
JT	AA + PT + TMA	Sticky	0.4±1.0 c	0.0±0.0 b

4. CONCLUSIONS

Results obtained suggest that the three component lure AA + PT+TMA (Biolure) in a MLT trap and the Israeli trap, were the ones that obtained the highest caPTure rates in most field tests and could be tested for use in mass trapping.

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IMPROVED ATTRACTANTS FOR MEDITERRANEAN FRUIT FLY, *Ceratitis capitata* (WIEDEMANN) AND OLIVE FRUIT FLY, *Bactrocera oleae* (GMELIN): TWO YEARS DATA EVALUATING THE RESPONSES OF WILD FLY POPULATIONS IN 3 SOUTHERN ITALY LOCATIONS

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Abstract

Tests were conducted during 2003 and 2004 on wild Mediterranean fruit flies (medfly), *Ceratitis capiata* (Wiedemann) and on olive fruit flies, *Bactrocera oleae* (Gmelin), in three locations in southern Italy. The tests with medfly were carried out in a citrus orchard in Sicily during 2003, from the end of September until the end of November, and in a peach orchard in Basilicata during the summer of 2004; while tests on olive fruit fly have been carried out both years in the same location in Apulia, starting in late August and finishing at the end of November. Among the 5 different baits used for the control of medfly in Sicily, the first records on the captures started during the 3rd week (mid October). Treatments B and C (AA+PT+TMA and AA+TMA, respectively) showed the best scores compared to the others and to the control (NuLure). Evaluating the captures among the 6 different baits utilized for the control of olive fruit fly in Apulia, first records started during the 3rd week (begin of September), and the best scores were detected on the traps with NuLure, showing a sex ratio in the captures of 1:1. Interesting data were recorded both years with the pheromone treatment (side experiment), showing a performance extremely high compared even with NuLure.

1. INTRODUCTION

The Mediterranean fruit fly (medfly), *Ceratitis capitata* (Wiedemann), is a major tephritid fruit fly pest of economic importance attacking over 300 different hosts, primarily temperate and subtropical fruits [1]. Medfly is distributed in tropical and subtropical areas of the world [2] and it is one of the most important pest in the Mediterranean region [3]. Countries where medfly is established must subject their host crops destined for export to costly quarantine treatments or regulated systems approaches [4] to reduce the risk of entry of medfly to areas where the fly does not exist. Each year, tens of thousands of semiochemical-based traps are deployed worldwide to detect or monitor medfly populations.

Olive fruit fly, *Bactrocera oleae* (Gmelin), is a very serious pest of olives wherever olives are grown in the Mediterranean basin (southern Europe, the Near East and northern Africa) where the vast majority of the world's olives are produced [5]. If left unchecked, it can infest 100% of the fruit on a tree, rendering the harvest unmarketable [6]. Besides its widespread distribution throughout the olive-growing Mediterranean region, *B. oleae* has been reported to occur in the Republic of South Africa, Kenya, Eritrea Sudan, India and Pakistan [7]; and recently invaded California and Northwest Mexico, the first record in Southern California was during the summer of 1998 [8].

Detection as well as control programmes have historically been carried out using semiochemical-based lures and attractants that attract males and/or females into traps that are monitored at regular intervals. When a fly is detected, trapping is increased in and around the initial find to further delimit the extent of the population [9]. The importance of early detection has always been a top priority in detection, delimitation and control programmes, as costs of intervention and eventual eradication increase dramatically if the population becomes established and spreads. For the last thirty years, Trimedlure (TML) (tert-butyl 4(and 5) chloro-2-methylcyclohexane 1-carboxylate) contained in Jackson traps, and McPhail traps baited with hydrolyzed protein were the primary detection tools used in medfly detection programmes [10]. Efforts to improve control and detection methods for medfly included development of both improved male lures such as Ceralure [11,9] and more recently female- based attractants [12,13,14].

The objective of the present work was the evaluation of fruit fly attractants for *C. capitata* and *B. oleae*, as a part of the Coordinated Research Program (CRP) "Development of improved attractants and their integration into fruit fly SIT management programmes" by the Joint FAO and IAEA programme.

Three field experiments were carried in Southern Italy: two for *C. capitata* respectively during the fall of 2003 and the summer 2004; and one for *B. oleae* in autumn 2003 and 2004.

2. MATERIALS AND METHODS

2.1. Experiment I: Medfly Trials

The test area selected was a 36 ha orange orchard, *Tarocco* and *Navel* cultivars, near Paternò, about 40 Km W of Catania, Sicily; the experiments have been carried out from September 26 to November 21, 2003 in a 2 ha area cultivated with *Navel* cv, one of the most suscePTible to medfly attacks. The orchard is at 100m altitude, and 30 years old trees are organised in a 6x6m distribution pattern. The experimental area was divided in 2 sub-plots for replicates 1 and 2. Each replicate was organised using five Multilure traps (MLT) (McPhail type) baited with the following treatments:

A: 250ml NL
B: AA+PT+TMA
C: AA+TMA
D: ½AA+TMA
E: ½AA+PT+TMA

Abbreviations: AA=Ammonium acetate, PT=Putrescine, TMA=Trimethylamine, NL=NuLure; in treatments from B to E, 250 ml of a 0,01% solution of the surfactant Triton was added to the bottom of the traps in order to break the surface tension and increase caPTure of attracted flies.

Treatment A (NuLure) was used as a positive control in order to compare the effectiveness of experimental treatments (B to E) with various synthetic food attractants.

Traps have been hung on the SE side of the canopy at 1,5-2m from the ground and at 24m distance from each other (4 rows); a 2-row buffer has been set all around the plot to avoid any "border effects".

In the replicates 1 and 2 treatment traps were exposed 6 days/week, while control was applied only in the day when replicates 1 and 2 were not applied.

Traps were serviced every three days, treatment A was renewed at every visit, while treatments B-E every 4 weeks. Traps were rotated at every visit, every three days. Climatic data were recorded by a nearby weather station (SOAT Paternò, n.19).

2.2. Experiment II: Medfly Trials

On the basis of the results of 2003 trials, treatment B (AA+PT+TMA = Biolure) was selected as the more suitable for Southern Italy climatic conditions.

In 2004 the field experiment was focussed on the evaluation of the combination of mass trapping system and bait stations in a pilot field test utilising Biolure in association with the Spinosad-based, baited bioinsecticide GF 120 (Dow AgroSciences).

The area selected for the experiment was a 12ha peach orchard cv. *Percoco* in an organic farm at 350m elevation at Senise, Basilicata, Southern Italy. The farm, located on the top of a small flat hill, has a peculiar position, very isolated from other farms. The only other medfly hosts available in the selected farm consist in 2ha apricot orchard, 5ha kiwi orchard and a natural population of *Opuntia* cactus.

The field trial was carried out from June 1st to September 4th, 2004. An area of 6ha was selected within the organic peach orchard, and divided in four 1ha sub-plots (treatments A-D):

A: mass trapping system, using 54 MLT traps;
B: application of GF 120 on 54 tree trunks;
C: combination of treatments A and B;
D: control (untreated).

Treatments A and C had 54 MLT traps baited with Biolure; GF 120 was applied in treatments B and C. The performance of the experiment was evaluated by 2 monitoring systems: 1 Trimedlure trap and 2 MLT traps baited with Biolure in each treatment, for medfly male and female detection respectively.

Traps were hung on the SE side of the tree canopy at 1.5-2m from the ground and at intervals of 20m (every 3 threes and every 2 rows); a 2-row buffer has been set all around the plot to avoid "border effect". A Deltametrine treated net (10 x 15cm) has been used as insecticide in each MLT trap.

GF-120 was applied every week in treatments B and C on the same selected trees spraying a small spot (5cm diameter) on the trunk of the trees at 130cm from the ground. The strategy used was to spray every five trees per row, every two rows, and all the trees along the border of the peach orchard; GF120 applications were repeated once a week for the entire period of the experiment experiment. Climatic data were recorded by a nearby weather station (S. Giorgio Lucano).

2.3. Experiment III: Olive Fruit Fly Trials

Site III – Serracapriola (2003-04)**.** The *B. oleae* experiment was run at Serracapriola, Foggia, Apulia. This area is one of the most important and productive olive regions of the world. We selected a 40ha olive plantation composed by 30 years old olive trees organized in a 6 x 4m displacement design. The experiment took place in a 3ha area within the plantation.

Trials were carried out between August and November of 2003 and 2004. The 3ha plot was divided into 5 sub-plots: replicates 1t o 4 and the control. Each replicate was organised using six MLT traps baited with the following treatments:

A: 250ml NL
B: 4 AB
C: 4 AB+TMA

D: 2 AB+TMA
E: 4 AB+PT
F: 2 AB+PT

Abbreviations: PT=Putrescine, TMA=Trimethylamine, NL=NuLure, AB=Ammonium Bicarbonate; in treatments from B to F, 250 ml of a 0,01% solution of the surfactant Triton was added to the bottom of the traps in order to break the surface tension and increase caPTure of attracted flies.

As the 2003 medfly experiment, NuLure baited traps were used as a positive control. Traps have been hung at 1.5-2m from the ground and at 20m distance by width and 30m by lenght from each other; a 15m by width and 24m by lenght buffer area has been set all around the plot to avoid any "border effects".

Replicates 1 to 4 have been applied 6 days/week, while the control was applied 1 day per week, when replicates 1-to 4 were not applied. Traps were serviced every three days, treatment A was renewed at every visit, while treatments B-F, once every 4 weeks. Traps were rotated at every visit.

In addition to the standard CRP protocol, sticky panel traps baited with synthetic female pheromone (Dacotrap, Isagro, Italy) were used in side experiments.

Climatic data were recorded by a nearby weather station (Serracapriola).

2.4. Data Analysis

Since collected data are not normally distributed, results were analysed using nonparametric methods such as Kruskal-Wallis test to assess the significance of the differences between treatments, and the Mann-Whitney and Wilcoxon test. The latter was used to test the differences between each treatment by means of pairwise comparisons. Statistical analyses were ran using SPSS, Windows platform.

3. RESULTS AND DISCUSSION

Medfly

2003 Experiment (Sicily)

Most probably due to the unusual climatic conditions recorded in Southern Italy during summer and fall 2003, characterized by very high daily temperatures, low relative humidity and prolonged absence of precipitation, the medfly population during 2003 was very low. Table I and FIG. 1 report mean weekly captures of *C. capitata* for treatments A-E; despite to the extremely low caPTure rate, the three component lure (Biolure, treatment B) resulted significantly more efficient than other tested compounds.

TABLE I. SUMMARY OF MEAN WEEKLY MALE AND FEMALE MEDFLY CAPTURES DURING 2003 SICILY EXPERIMENT; STD. DEVIATION (SD) AND STD. ERROR OF MEAN (SEM) ARE REPORTED.

	Males Kruskal-Wallis test; χ^2=19.105; P<0.01				Females Kruskal-Wallis test; χ^2=22.449; P<0.01			
Treatment	N	Mean Captures[a]	SD	SEM	N	Mean Captures[a]	SD	SEM
A - NuLure	32	0.00 c	0.00	0.00	32	0.41 c	0.67	0.12
B - AA+PT+TMA	32	0.56 a	0.88	0.16	32	2.41 a	2.23	0.39
C - AA+TMA	32	0.09 bc	0.30	0.05	32	1.31 b	1.65	0.29

			Males Kruskal-Wallis test; χ^2=19.105; P<0.01					Females Kruskal-Wallis test; χ^2=22.449; P<0.01		
D - ½ AA+TMA	32	0.09	bc	0.30	0.05	32	0.63	bc	0.91	0.16
E - ½ AA+PT+TMA	32	0.16	b	0.37	0.07	32	1.34	ab	1.49	0.26

Treatments followed by the same letter showed median values not significantly different (Mann-Whitney and Wilcoxon test; P<005; U and W sig. indexes not reported)

Among the 5 different baits used, treatments B (AA+PT+TMA) showed the highest attractancy towards *C. capitata* in both replicates, producing better results than the control using NuLure. Treatments C (AA+TMA) and E (½AA+PT+TMA) showed good scores if compared with the control. All baits showed marked selectivity for females.

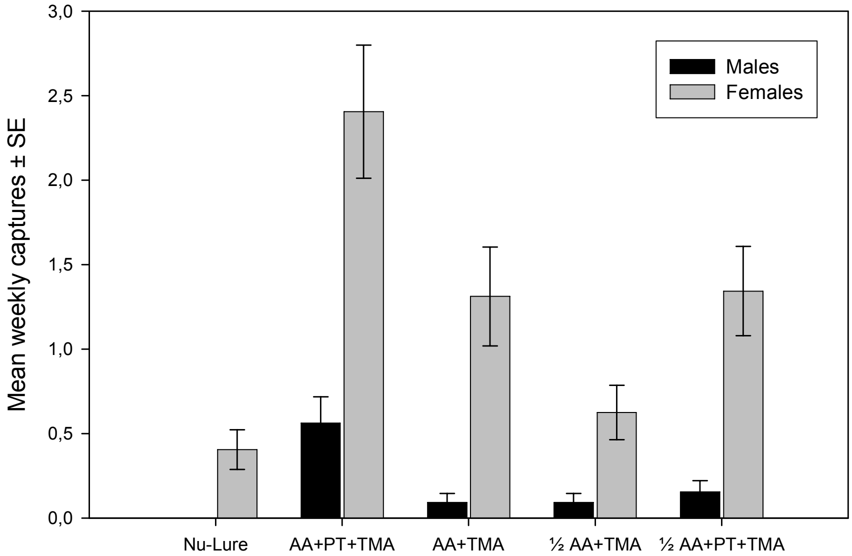

FIG. 1. 2003 medfly experiment; mean weekly male and female captures.

2004 Experiment (Pollino)

Table II reports the mean number of female medfly captures on Biolure-baited monitoring traps: the decrease of captures in treatments A, B, and C clearly shows the impact that the 3 mass trapping strategies had on the occurrence of wild medfly population in treated plots versus the control plot.

TABLE II. MEAN WEEKLY MEDFLY CAPTURES ON BIOLURE (AA+PT+TMA) BAITED MONITORING TRAPS DURING 2004 POLLINO EXPERIMENT; STD. DEVIATION (SD) AND STD. ERROR OF MEAN (SEM) ARE REPORTED.

Treatment		N	Mean Captures[a]		SD	SEM
A	AA+PT+TMA PMT	18	22.33	b	26.09	14.00
B	Baited spinosad	18	44.94	a	53.39	12.34
C	AA+PT+TMA PMT+ Baited spinosad	18	9.50	c	12.23	10.18
D	Control	18	78.56	a	85.64	21.43

[a]Treatments followed by the same letter showed median values not significantly different (Mann-Whitney and Wilcoxon test; P<005; U and W sig. indexes not reported)

The graph in FIG. 2 shows the mean weekly captures on Trimedlure baited pagoda and Biolure baited MLT traps, used to track the presence of males and females respectively, in plots A-D. Medfly infestation in plot C, treated with GF-120 alone, showed a decrease of more than 40% when compared with the control plot, still keeping a captures sex ratio close to 1:1, confirming that the bait associated with Spinosad in GF-120 is not sexually selective. Moreover, in plot B, where mass trapping with Biolure baited MLT traps was applied, only limited differences in male captures (TML trap) was highlighted, but a notable decrease of more than 60 % in the presence of females (Biolure traps) when compared with control plot (D).

The remarkable effect on female medfly population is even stronger on combination of both mass trapping and bait station strategies (plot C): the decrease of male captures is not significantly different from the data observed in plot C (GF-120 alone treatment), while the captures of females drop down to less than 15% when compared with control.

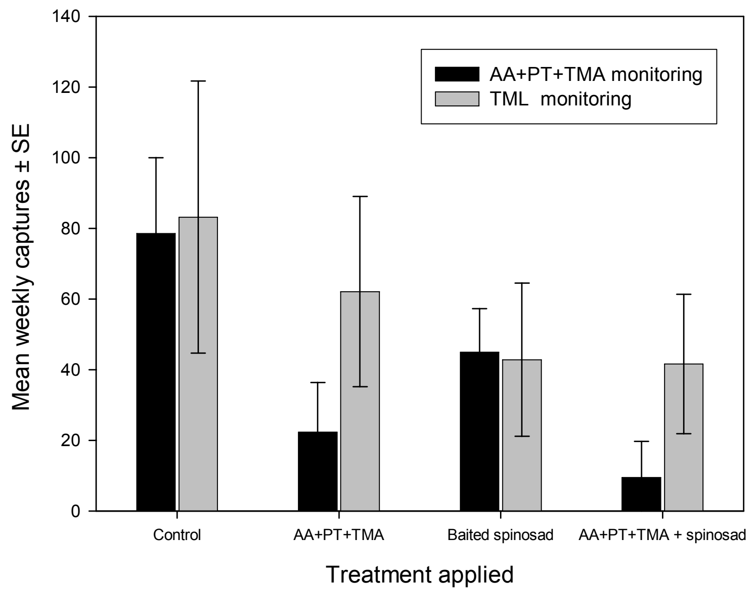

FIG. 2. 2004 medfly experiment; mean weekly captures on Biolure (AA+PT+TMA) and Trimedlure (TML) baited monitoring traps.

While weekly captures on Biolure traps showed significant differences (Kruskal-Wallis test; P<0.01, table 2), captures on TML baited traps did not evidence any significant difference between A-D treatments.

Olive Fruit Fly

2003-2004 Experiments. Climatic conditions of summer and fall 2003 also influenced the presence of olive fruit fly populations in Southern Italy; fruit samples collected during field trials showed a *B. oleae* emergence rate lower than 3%.

Nevertheless, it was possible to evidence significant differences between the baits used in tests conducted in 2003 (FIG 3). The 2004 repetition of the experiment showed compatible results with tests from previous year (FIG. 4).

Tables 3 and 4 report mean Captures, standard deviation and standard error of *B. oleae* Captures for 2003 and 2004 tests, respectively. Olive fruit fly males and females clearly showed to prefer NuLure, when compared to the different combinations of AA, TMA and PT. Between them, treatments E and F (respectively 4AB+PT and 2AB+PT) showed significantly higher scores.

Interesting data were highlighted in the side experiment where the female pheromone showed an extremely high performance (of course only with males); in addition the captures un pheromone baited traps started almost a week earlier than the captures on NuLure traps.

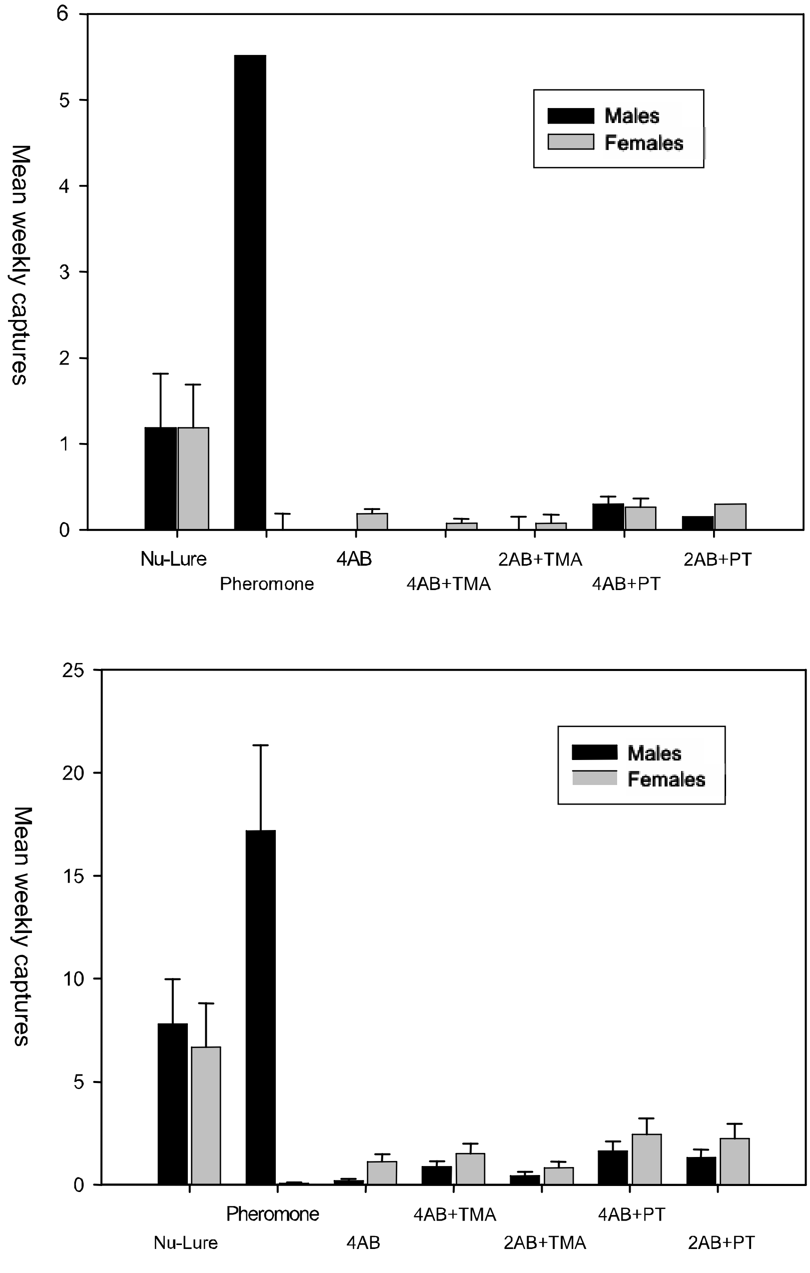

FIG. 3. Summary of mean (±SE) weekly B. oleae *captures in 2003 (above) and 2004 (below) experiments in Apulia.*

Although infestation rates in 2003 were extremely low, tests evidenced similar relative results in both years.

4. CONCLUSIONS

Our studies have shown that between medfly response to ammonia based lures, Biolure, remains the best as female medfly attractant, and can be used for monitoring as well for mass trapping approaches.

In addition, the studies carried out during 2004 indicated an effective synergistic effect of the combination of Biolure mass trapping with the Spinosad-based bait GF-120. This strategy, which aims to oPTimise the use and application of Spinosad, seems to be quite efficient for the control of medfly, at least in the areas of Southern Italy where tests were conducted.

The most effective were NuLure and the synthetic female pheromone, with scores that would allow their use for monitoring olive fruit fly females and males respectively.

None of the attractants tested with *B. oleae* wild populations appears to be promising for a mass trapping approach.

TABLE III. MEAN WEEKLY OLIVE FRUIT FLY CAPTURES IN 2003 APULIA EXPERIMENT; STD. DEVIATION (SD) AND STD. ERROR OF MEAN (SEM) ARE REPORTED.

Treatment		N	Mean males[a]		SEM	SD	Mean females[a]		SEM	SD
A	Nu-Lure	27	1.19	b	0.63	3.28	1.19	a	0.51	2.63
B	4AB	27	0.00	d	0.00	0.00	0.19	b	0.05	0.96
C	4AB+TMA	27	0.00	d	0.00	0.00	0.07	bc	0.05	0.27
D	2AB+TMA	27	0.00	d	0.15	0.00	0.07	bc	0.10	0.27
E	4AB+PT	27	0.30	c	0.09	0.78	0.26	ab	0.10	0.53
F	2AB+PT	27	0.15	cd	0.00	0.46	0.30	ab	0.00	0.54
	Pheromone	27	5.52	a	0.00	6.26	0.00	c	0.19	0.00

[a]Treatments followed by the same letter showed median values not significantly different (Mann-Whitney and Wilcoxon test; P<005; U and W sig. indexes not reported)

TABLE IV. MEAN WEEKLY OLIVE FRUIT FLY CAPTURES IN 2004 APULIA EXPERIMENT; STD. DEVIATION (SD) AND STD. ERROR OF MEAN (SEM) ARE REPORTED.

Treatment		N	Mean males[a]		SEM	SD	Mean females[a]		SEM	SD
A	Nu-Lure	16	7.81	a	2.19	8.74	6.69	a	2.13	8.53
B	4AB	16	17.19	a	4.18	16.71	0.06	c	0.06	0.25
C	4AB+TMA	16	0.19	c	0.10	0.40	1.13	b	0.36	1.45
D	2AB+TMA	16	0.88	bc	0.26	1.02	1.50	b	0.50	2.00
E	4AB+PT	16	0.44	bc	0.18	0.73	0.81	bc	0.31	1.22
F	2AB+PT	16	1.63	b	0.47	1.89	2.44	ab	0.80	3.18
	Pheromone	16	1.31	b	0.41	1.62	2.25	b	0.72	2.86

[a]Treatments followed by the same letter showed median values not significantly different (Mann-Whitney and Wilcoxon test; P<005; U and W sig. indexes not reported)

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EVALUATION OF DIFFERENT TRAPPING SYSTEMS FOR USE IN MEDITERRANEAN FRUIT FLY STERILE INSECT TECHNIQUE (SIT) PROGRAMMES

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Abstract

In the Madeira Island of Portugal, where a SIT suppression programme against Mediterranean fruit fly, *Ceratitis capitata* (Wied.) is in operations, several trap types, fruit fly food based attractants and retention systems (killing agents) were tested with the aim of developing improved female biased trapping systems in support of area-wide SIT Programmes. In contrast with male specific trapping systems, which for many years have been used in medfly SIT programmes as monitoring and detection tools, and which catch too many of the released sterile males, female biased trapping systems have shown to be more sensitive for early detection and catch predominantly females, but still sufficient sterile males to keep track of the released sterile males. These experiments were conducted from 2001 to 2005 under different climatic conditions and hosts. The traps tested were: Jackson, Tephri, Multilure (MLT), Shabtiely and Easy. The attractants tested were: NuLure, Ammonium Acetate (AA), Putrescine (PT), Trimethylamine (TMA), and Trimedlure and the retention systems tested were: DDVP, water and Triton, water and Propylene Glycol, three different sizes of Deltamethrinee (DM) impregnated fabrics (UV PermaNet): 16, 64 and 256 cm^2, mosquito net (UV PermaNet), blue panel (UV PermaNet), DM dog collars, and sticky inserts. In conclusion, the MLT trap baited with TMA+AA+PT and the retention system based on fabric UV PermaNet (256 cm^2) was the best treatment. The dog collar and mosquito net (easy to find in the local market) were also good options as retention systems. The Shabtiely trap, because of the lack of a retention system, is less labour intensive does not use a toxic agent to retain fruit flies that have been trapped and thus could be a good choice in urban and suburban areas were children have easy access.

1. INTRODUCTION

Over the last years there has been considerable progress in the development of new traps and attractants for Mediterranean fruit fly (medfly), *Ceratitis capitata* (Wied.) [1]. Based on that, female biased olfactory attractants are now important tools for monitoring and detection in medfly area-wide control programmes [2]. With the recent banning in Europe of the insecticide Dichlorvos (DDVP) and Malathion, commonly used as killing agents (retention systems) inside fruit fly traps, the need to evaluate new more cost-effective retention systems has emerged. The combination in traps of these female biased attractants with a cost-effective retention system could potentially be used as a population suppression method to mass trap females in certain locations without interfering with the release of sterile males [4].

The Madeira Island is located in the Atlantic Ocean (32ºN, 17ºW), with a variable climate depending on the altitude. The north/south coast has good conditions for medfly development throughout the year [5].

Between the years 2000 and 2005, several experiments with different types of traps using different retention systems and female biased medfly attractants were conducted. The aim was to look for an effective and non-labour intensive trapping system that allowed the growers in Madeira Island the use of traps, not only for medfly monitoring, but also as a control tool. Furthermore, in this Island where the main economic activity is tourism, it is necessary to find environment friendly alternatives to chemical control to suppress wild population of *C. capitata* before and during the release of sterile male medflies.

2. MATERIAL AND METHODS

Six experiments using different trapping systems (traps, killing agents and combinations of the dry synthetic food lures) were conducted in different locations in the island under different climatic conditions (FIG.1).

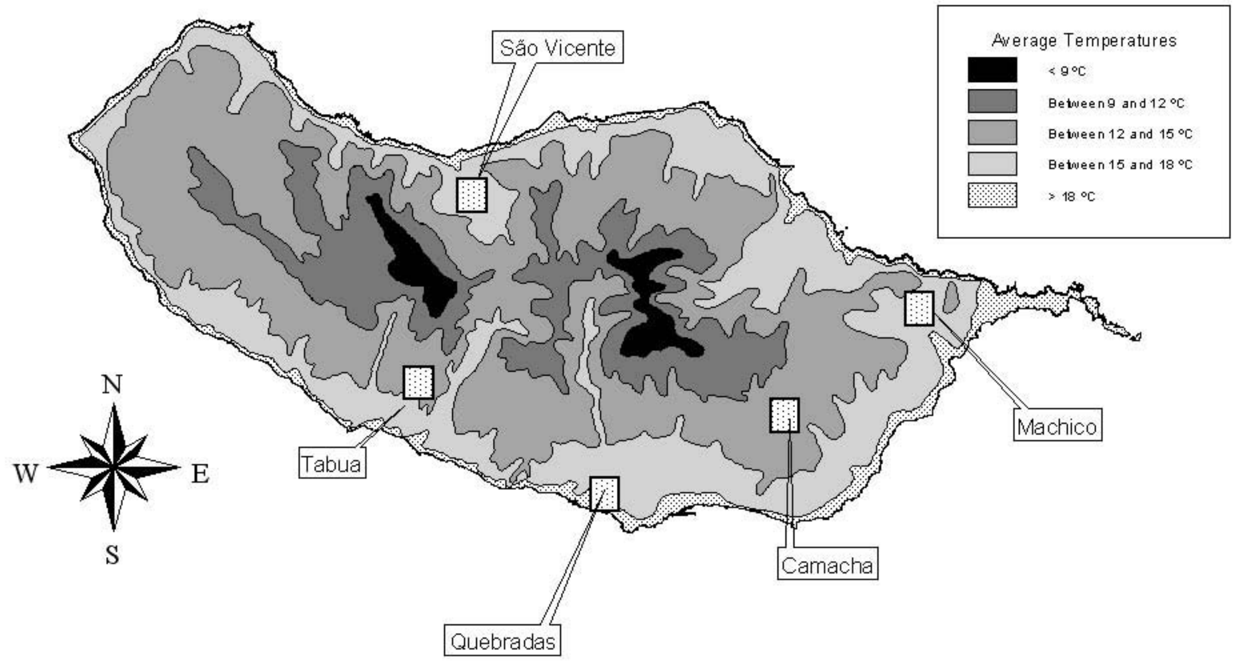

FIG.1 –Location of the experiments conducted in Madeira Island.

In all six experiments traps were placed in orchards bearing the most common fruit host grown in the area. Trees of the same size and presenting the same phenology (e.g. fruiting condition) were chosen. The traps in each block (replicate) were rotated sequentially after each visit. The traps were hung in the upper two thirds of the southeastern part of the tree canopy, avoiding leaf contact. The traps were placed equidistant between 15 to 25 meters apart. In studies 1, 2, 3 and 4, the retention systems were replaced weekly and traps were checked for fruit fly captures twice a week.

2.1. Experiment 1

The first experiment was conducted between 7 of August and 17 of September 2001, during six weeks in the south coast in a naturally wild medfly infested area. It was done at two different elevations, one at 100m altitude (Quebradas) in an orchard with different varieties of Mango (*Mangifera indica)* and the other at 700m altitude (Camacha) in an orchard with mainly Pears (*Pyrus communis)* and apples (*Malus communis*). Each experiment consisted of five blocks, with six different treatments (Table I) using the same trap type (i.e. Multilure trap (MLT)). In all blocks traps were ordered from A to F.

TABLE I. TREATMENTS USED IN EXPERIMENT 1 (7 OF AUGUST TO 17 OF SEPTEMBER 2001)

Treatment	Trap	Attractant	Retention System
A	MLT	NuLure	300 ml solution with 9% NuLure, 3% Borax and 88% of water
B	MLT	AA + PT + TMA	300 ml water/ 2 drops Triton at 10%
C	MLT	AA + TMA	30 ml Propylene Glycol and 270 ml water
D	MLT	AA	DDVP plug
E	MLT	AA + PT	Cotton with Deltamethrinee
F	MLT	AA + PT + TMA	Sticky insert

2.2. Experiment 2

This experiment was conducted from 21 of January to 4 of March 2002, during six weeks in the north and south coasts. On the south coast (Quebradas) in the same orchard used in experiment 1, and on the north coast at 400m altitude (São Vicente Valley) in an area under sterile fly release in a sweet orange (*Citrus sinensis*) orchard .

The protocol used was the same than in Experiment 1, excePT for treatment A that was not used, and an additional treatment was introduced and coded as G (only in São Vicente Valley). Each experiment consisted of five blocks, each with six different treatments. In all blocks traps were ordered from B to G. For treatments B, C, D, E, F, the traps, attractants and retention systems used were the same as those used in experiment 1. Treatment G, was the conventional Jackson trap baited with Trimedlure and a sticky insert as retention system.

2.3. Experiment 3

From 17 of February to 10 of April 2003, different experiments were conducted simultaneously in two places in the southern part of the island. In the Machico Valley with an altitude of 330m, where custard apple (*Annona cherimolia)* is commercially grown and sterile flies are continuously released. In Tabua with an altitude of 350m, where sweet orange is grown (FIG.1). Seven treatments were used according to Table II and placed in 5 blocks. The experiments were on the field for 8 weeks and the trap data collected twice a week.

TABLE II. TREATMENTS USED IN EXPERIMENT 3 (17 OF FEBRUARY TO 10 OF APRIL 2003)

Treatment	Trap	Attractant	Retention System
A	MLT	NuLure	NuLure/Water
B	MLT	AA + PT + TMA	Water/Triton
C	MLT	AA + TMA	Water/Triton
D	MLT	AA	Water/Triton
E	MLT	AA + PT	Water/Triton
F	MLT	AA + PT + TMA	Sticky insert
G	Tephri	AA + PT + TMA	DDVP

2.4. Experiment 4

This experiment was conducted during 8 weeks, from 22 of October to 19 of December 2003, in the same orchards than those conducted in experiment 3. Seven treatments as indicated in Table III and V blocks were used.

TABLE III. TREATMENTS IN EXPERIMENT 4 (22 OF OCTOBER TO 19 OF DECEMBER 2003)

Treatment	Trap	Attractant	Retention System
A	MLT	NuLure	NuLure/Water
B	MLT	AA+PT+TMA	Water/Triton
C	MLT	AA+TMA	Water/Triton
D	MLT	1/2AA+TMA	Water/Triton
E	MLT	1/2AA+PT+TMA	Water/Triton
F	Shabtiely	AA+PT+TMA	None (starvation)
G	Jackson	AA+PT+TMA	Sticky insert

2.5. Experiment 5

This experiment was conducted in Machico Valley, (FIG.1) from 12 of July to 6 of December 2004, in same orchard as experiment 3. Different trap designs were compared (Tephri, Multilure, Shabtiely and Easy). All traps baited with the same attractants: PT+AA+TMA but with different killing agents: DDVP, water and Triton, starvation, nets (UV, PermaNet) and fabrics (UV, PermaNet) in three different sizes: 16, 64 and 256 cm^2. These nets and fabrics were maintained inside the trap, in the upper part.

The experiments were conducted using 20 treatments as indicated in Table IV and 3 blocks. The experiments were on the field for 8 weeks and the trap data collected twice a week.

TABLE IV. TREATMENTS USED IN EXPERIMENT 5 (12 OF JULY TO 6 OF DECEMBER 2004)

Treatment	Trap	Attractant	Retention System
A	Tephri	TMA + AA + PT	Net [1]
B	MLT	TMA + AA + PT	Net [1]
C	Tephri	TMA + AA + PT	Net [2]
D	MLT	TMA + AA + PT	Net [2]
E	Tephri	TMA + AA + PT	Net [3]
F	MLT	TMA + AA + PT	Net [3]
G	Tephri	TMA + AA + PT	Fabrics [1]
H	MLT	TMA + AA + PT	Fabrics [1]
I	Tephri	TMA + AA + PT	Fabrics [2]
J	MLT	TMA + AA + PT	Fabrics [2]
L	Tephri	TMA + AA + PT	Fabrics [3]
M	MLT	TMA + AA + PT	Fabrics [3]
N	Tephri	TMA + AA + PT	Water + Triton
O	MLT	TMA + AA + PT	Water + Triton
P	Tephri	TMA + AA + PT	DDVP
K	MLT	TMA + AA + Put	DDVP
R	Easy T	TMA + AA + PT	Net [2]
S	Easy T	TMA + AA + PT	Fabrics [2]
T	Easy T	TMA + AA + Put	DDVP
U	Shabtiely	TMA + AA + PT	Starvation

[1]Small size, a 16 cm^2 square
[2]Medium size, a 64 cm^2square
[3]Large size, a 256 cm^2 square

2.6. Experiment 6

This experiment was conducted from January to March 2005 in Quebradas (FIG.1) in the same orchard as experiment 1.In this experiment only the Multilure trap was used with different retention systems as indicated in Table V. The blue panel and mosquito net (UV, PermaNet) was maintained inside the trap, in the upper part. The experiments were conducted with 4 treatments and 4 blocks. The experiments were on the field for 4 weeks and the trap data was collected twice a week.

TABLE V. TREATMENTS USED IN EXPERIMENT 6 (JANUARY TO MARCH 2004)

Treatment	Trap	Attractant	Killing agent
A	MLT	NuLure	NuLure + Water
B	MLT	TMA + AA	Dog collar[1]
C	MLT	TMA + AA	Blue pannel[2]
D	MLT	TMA + AA	Mosquito net[2]

[1]Scalibor with 32.5cm
[2]Square with 256 cm^2

3. RESULTS

3.1. Experiment 1

Treatments B (MLT trap + AA+PT+TMA + 300 ml water/Triton), C (MLT trap + AA+TMA + 300 ml Propylene Glycol and 270 ml water) and D (MLT trap + AA + DDVP) showed the best results for both locations. In relation to the percentage of females we found different results according to the population level. In Quebradas the percentage ranged between 50 and 67 in all treatments. In Camacha, with low population the percentage ranged between 89 and 100. This data is supported by previous studies in Madeira [6]. During these experiments in Quebradas the minimum average temperature was 21 ºC and the maximum 28 ºC. The relative humidity (RH) was more than 55%. At

Camacha, the minimum average temperature was 12.5ºC and the maximum 21 ºC. The RH was more than 80% during all the test period.

3.2. Experiment 2

According to the fly per trap per day (FTD) population index and the percent Captures, treatments B (AA+PT+TMA + Triton), C (AA+PT+TMA + PG) and D (AA + DDVP) showed better results for Quebradas. In the experiment conducted in São Vicente Valley, Jackson Trap was used as relative control and captured 2.5 times more flies (mostly sterile males) than the second more effective treatment C (AA+PT+TMA +PG) which captured both wild females and wild and sterile males. In this experiment the better result in terms of FTD and percent of females was obtained in treatments C and B (liquid retention system).

In relation to female trap efficiency, all traps presented similar results. In general the percent of females caught was high. 77.8% was the best result and was obtained in treatment F (AA+PT+TMA + sticky insert). Treatment C (AA+PT+TMA + PG) and B (AA+PT+TMA + Triton) captured 69.9 and 68.2 percent females, respectively. The minimum average temperature registered in Quebradas was 12ºC and the maximum 20ºC. The RH was more than 65% during nearly all of the test period. Rain occurred for 9 days (maximum 29mm). At São Vicente Valley the minimum average temperature was 10 ºC and the maximum 18 ºC. The RH was above 70% during all the test period. Rain occurred for 16 days, with a maximum value of 47 mm in a day.

3.3. Experiment 3

According to the results the best treatment in Tabua orchard was E (MLT trap + AA+PT) with water and Triton as retention system. When comparing results of treatment G (Tephri Trap + AA+PT+TMA and DDVP) with treatment B (MLT trap + AA+PT+TMA and water/Triton), one could infer that DDVP has a repellent effect.

In the Machico orchard, under sterile male releases, the use of the attractant AA+PT+TMA was the best option. In relation to the retention system, water/Triton was the best in both places, Machico and Tabua. In this orchard were the maximum temperature was 24ºC, not as high as in Tabua with 31ºC, treatment C (PMT + AA+TMA + water/Triton) captured more females than treatment E (PMT + AA+PT + water/Triton).

3.4. Experiment 4

In Tabua orchard without the sterile fly releases the proportion of males was higher than females. The best results was obtained by treatment B (MLT traps + AA+PT+TMA + water/Triton), followed by treatment E (MLT traps + 1/2AA+PT+TMA + water/Triton) and F (Shabtiely + AA+PT+TMA + no retention system). Treatment F, without a retention system, has the advantage of not using toxic product as retention system and that it is less labour intensive as there is no need to replace the retention system

In Machico orchard, under sterile male releases, the synthetic attractant AA+PT+TMA was the best, capturing large numbers of females. The Shabtiely trap without any retention system showed to be very effective. These results were obtained with a temperature ranging between 12 and 26 ºC.

3.5. Experiment 5

The Easy trap baited with AA+PT+TMA captured approximately the double amount of males compared with the MLT trap and approximately the same amount of females. According to these results the use of the Easy trap would represent a problem in areas were sterile males are released. In relation to the retention systems, results showed that the DM impregnated fabric (UV PermaNet) 256 cm^2 in size, was the best system, capturing more flies and remaining more time in the field. The

Shabtiely trap without any killing agent captured more females than males but in lower quantities then the other traps. This trap has the advantage to eliminate the weekly use of water and insecticides being a good choice for urban areas were children could have easy access. These results were obtained with a temperature that ranged between 12 and 39 ºC.

3.6. Experiment 6

In this experiment, the best treatment was the MLT trap baited with NuLure. The best of the treatments using the synthetic attractant AA+PT+TMA was the one with the dog collar as a retention system, showing no difference compared with the mosquito net (UV PermaNet) 256cm^2 in size. These results were obtaining with a temperature that ranged between 8 and 29 ºC.

4. Conclusion

From these experiments conducted under the conditions of the Madeira Island, we have concluded that the most effective attractant is the TMA+AA+PT capturing a very large number of females and also substantial amounts of males. However, the number of captures was affected by the type of trap used. From all the traps tested, the Easy trap was the best one, considering the total number of females and males captured and also the amount of hand labour involved. However, given the high number of sterile males captured in the Easy trap, the MLT trap seems to be more appropriate since it captures the same amount of females but much less males. According to these results, the best retention system for the traps tested is the fabric UV, PermaNet with 256 cm^2 in size.

ACKNOWLEDGEMENTS

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EVALUATION OF DIFFERENT BAIT STATIONS SYSTEMS FOR USE IN MEDITERRANEAN FRUIT FLY STERILE INSECT TECHNIQUE (SIT) PROGRAMMES

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Abstract

Over the last years efforts have been done to develop an effective bait station system, less expensive than the current trapping systems. The aim is to develop a cost-effective control method for use by farmers and as part of area-wide SIT programmes to suppress female populations in areas where conventional insecticide bait sprays cannot be used. During three years several experiments were conducted under different climatic conditions and hosts. The following materials were tested: 1) SolBaitGel, 2) GF120 field dilution + 400 ppm Imidachloprid + 7.6% starch, 3) GF120 field dilution + 400 ppm Imidachloprid + 7.6% starch + 1% Model 8 (DSM), 4) GF120 field dilution + 400 ppm Imidachloprid + 7.6% starch + 1% Model 8 (DSM) + 0.2% Methyl Pyrrolidine, 5) GS-AA, 6) GS-Patch, 7) GS-ATMAA, 8) Solbait + AA, 9) Solbait + model 20, 10) Solbait + model 24, and 11) AA+TMA patch, to test their effectiveness as female attractants for potential use as bait stations. In conclusion, only the Solbait + model 20 and GS-Patch showed to caPTure significant amounts of medfly females under the climatic conditions of the Madeira Island.

1. INTRODUCTION

Between the years 2003 and 2005, several experiments with different types of bait stations were conducted. The aim was to develop a cost-effective control method for use by farmers and as part of area-wide SIT programmes to suppress female populations in areas of the Madeira Island where conventional insecticide bait sprays cannot be used. The approach is to combine a long lasting bait and retention system without a trap support, which is at the same time non-labor intensive and of a cheap material.

The Madeira island is located in the Atlantic Ocean (32ºN, 17ºW), and it has a variable climate depending on the altitude, however, condition throughout the year are good for medfly development [1]. The base of the economy in the island is the tourist industry, and ecotourism is one of the main activities. Thus, it is of critical importance to develop environment friendly medfly control alternatives for suppression of populations before and during the sterile male releases.

2. MATERIALS AND METHODS

Because the aim was to evaluate the attractiveness of these baits it was necessary to use the new materials together with traps. In all studies traps were placed in orchards bearing the most common fruit host grown in the area. Trees of the same size and presenting the same phenology (e.g. fruiting condition) were chosen. The traps in each block (replicate) were rotated sequentially after each visit. The traps were hung in the upper two thirds of the southeastern part of the tree canopy, avoiding leaf contact. The traps were placed equidistant between 15 to 25 meters apart.

Several experiments using different materials and with different objectives were conducted in different places: Quebradas, Machico, and Tabua in Madeira Island (FIG.1).

All the attractants that tested were developed by the United States Department of Agriculture (USDA).

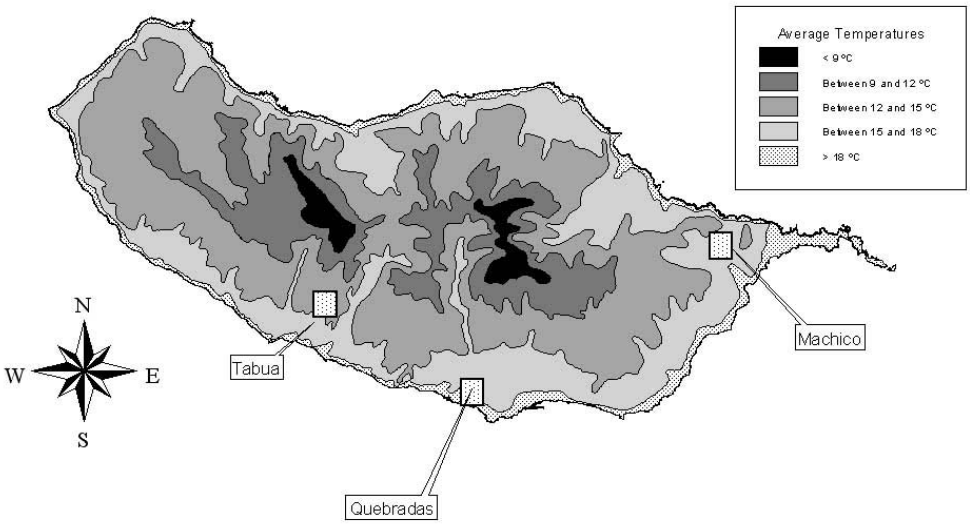

FIG.1 Location of the experiments conducted in Madeira Island.

2.1. Bait Station Gel

A mixture composed by protein and sugar as a feeding attractant based on the Solbait formulation that is used in the GF 120 bait was tested. The experiments were conducted between 7 July and 25 September and between 17 October and 5 December 2003 in Quebradas (Fig.1) at 100m of altitude above the sea level, in an orchard with different varieties of Mango *(Mangifera indica)*. Experiments were conducted in 4 blocks (replicates) each one with 5 treatments as shown in Table I.

TABLE I. TREATMENTS USED IN THE BAIT STATION GEL EXPERIMENTS FROM JULY TO DECEMBER 2003.

Treatment	Trap	Attractant	Retention System
A	Jackson	SolBaitGel, no insecticide	Sticky
B	Jackson	GF120 field dilution + 400 ppm Imidachloprid + 7.6% starch	Sticky
C	Jackson	GF120 field dilution + 400 ppm Imidachloprid + 7.6% starch+ 1% Model 8 (DSM)	Sticky
D	Jackson	GF120 field dilution + 400 ppm Imidachloprid + 7.6% starch + 1% Model 8 (DSM) +0.2% Methyl Pyrrolidine	Sticky
E	Jackson	AA + PT + TMA	Sticky

For this study we used Jackson traps baited with different lures (Table I). The control treatment was Jackson traps baited with Ammonium acetate (AA), Putrescine (PT), and Trimethylamine (TMA).

Traps were serviced twice a week. Captured insects were separated into wild males and wild females and transformed into flies per trap per day (FTD).

2.2. Bait Patches

This study was conducted in Quebradas (FIG.1) at the south coast of the Madeira Island, between 2 of February and 15 of March 2004, in the same orchard as bait station gel study. Five blocks were used each one with 3 treatments. The Jackson trap baited with different lures was used for the 3 treatments as indicated in Table II. Traps were serviced twice a week. Captured insects were was separated in wild males and wild females and transformed into FTD.

TABLE II. TREATMENTS USED IN BAIT PATCHES STUDY DURING FEBRUARY AND MARCH 2004.

Treatment	Trap	Attractant	Retention System
A	Jackson	GS-AA	Sticky
B	Jackson	GS-Patch	Sticky
C	Jackson	GS-ATMAA	Sticky

2.3. Patch Stations

This study was conducted between January and March of 2005 in Quebradas (FIG.1). The experiment was replicated 4 times and ran for 8 weeks. Attractants tested were based on the Solbait formulation that is used in the GF 120 bait as shown in Table III. The bait is based on microbial hydrolysed corn protein, sugar and a series of oils, thickeners and adjuvant applied either to the absorbent material used to present the bait or mixed with the Solbait. The GF 120 uses Spinosad as the killing agent at a recommended concentration of 80 ppm. GF 120 is shipped as "Success .02" which has a concentration of Spinosad of 200 ppm and is diluted when mixed.

Traps were serviced twice a week. Flies were removed and water replaced.

TABLE III. TREATMENTS USED IN THE PATCH STATIONS STUDY DURING JANUARY AND MARCH 2005.

Treatment	Funnel	Multilure trap
A	Solbait + Imidachloprid	-
A1	-	Solbait; water + Triton
B	Solbait + AA+ Imidachloprid	-
B1	-	Solbait + AA; water + Triton
C	Solbait + model 20+ Imidachloprid	-
C1	-	Solbait + model 20; water + Triton
D	Solbait + model 24+ Imidachloprid	-
D1	-	Solbait + model 24; water + Triton
E	NuLure+ Imidachloprid	-
E1	-	NuLure + water

Baits were presented as patches of absorbent material and were attached inside of MLT traps or as patches hung in the field above funnels to catch the falling flies. In the patches that use funnels, Imidochloprid was mixed for a fast fly kill and fall into the funnel. Insecticide was not used inside MLT traps.

2.4. Yellow Sphere and Patch Stations

This experiment was conducted between February and March 2005 in Machico (FIG.1) using a randomized complete block with 7 treatments and 5 blocks (Table IV). This test was in the field for 4 weeks and the trap data was collected weekly. One of the objectives was to compare the combined effect of colour, shape (round) and odour (yellow sphere) against the odour with no colour and shape effect (patch stations). In this test the attractant used in all treatments was the TMA+AA. MLT trap, dry and wet, with the same attractants was used as control. In treatments were insecticide (Imidachloprid or Methomyl syrups) was used as killing agent, a 30 cm diameter white funnel with a vial on the narrow part was kept 5 cm under the attractant to collect the flies. The vial was kept with water and Triton.

For the yellow sphere an insecticide solutions was used: Methomyl solution: 5 g of active ingredient Methomyl + 500 g of sugar and 250 ml of tap water. Imidachloprid solution: 150 mg of active ingredient Imidachloprid + 500 g sugar and 250ml tap water. The attractants were placed inside the spheres. Syrups were applied in the lower ¾ of each sphere using a paintbrush. The same was done with glue (sticky yellow sphere). Bait Patch with insecticide was ready for use.

TABLE IV. TREATMENTS USED IN THE YELLOW SPHERE AND PATCH STATION EXPERIMENTS DURING FEBRUARY AND MARCH 2005.

Treatment	Trap	Attractant	Retention System
A	MLT	TMA + AA	Water + Triton
B	Yellow sphere	TMA + AA	Sticky (in 3/4 of the sphere)
C	Funnel	TMA + AA	Methomyl (around the patch)
D	Funnel	TMA + AA	Imidachloprid (around the patch)
E	MLT	TMA + AA	DDVP
F	Yellow sphere+funnel	TMA + AA	Methomyl+sugar(in 3/4 of the sphere)
G	Yellow sphere+funnel	TMA + AA	Imidachloprid+sugar (in 3/4 of the sphere)

In the case of the patch stations, treatments C and D, were composed of one pack of TMA staked on one AA pack, both with insecticide Methomyl or Imidachloprid impregnated around the outside of the patch.

3. RESULTS

3.1. Bait Station Gels

Treatments B, C and D in both experiments presented similar results for male captures (FIG.2). However, treatment B (GF120 field dilution + 400 ppm Imidachloprid + 7.6% starch) presented the highest female captures. The best treatment was the control E (Jackson trap baited with AA+PT+TMA), which in the second study presented an unexpected high number of male captures.

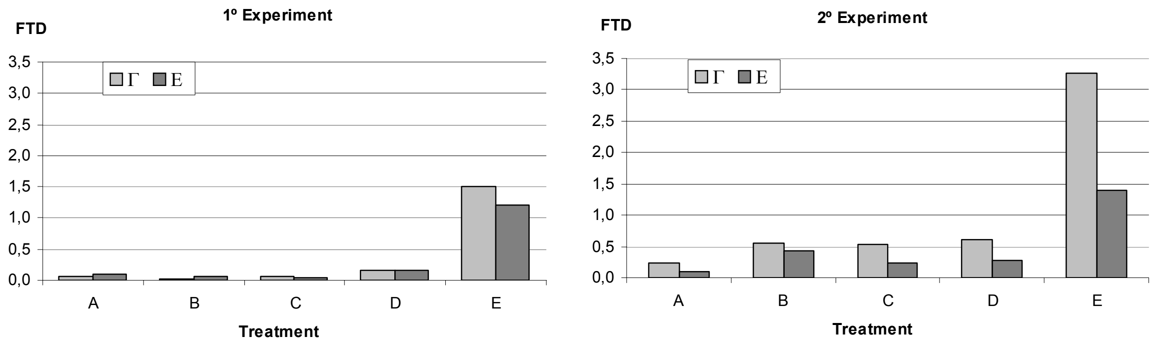

FIG. 2. Number of flies, males and females, captured per trap per day (FTD), in experiments 1 and 2.

3.2. Bait Station Patches

In this study the best treatment was B (GS-Patch) (FIG.3).

3.3. Patch Stations

The results of this study showed very small numbers of captured flies in the funnels when compared whit MLT baited whit the same attractant (FIG 4). This could indicate that flies are attracted to these materials but the toxic effect of the insecticides is not fast enough allowing flies to escape. Comparing the attractiveness of all the tested components, the NuLure (E) and the Solbait + model 20 + water + Triton (C1), were the most efficient.

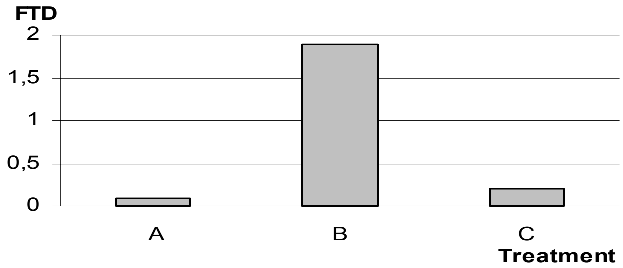

FIG. 3. Number of flies captured per trap per day (FTD) in Bait station patches.

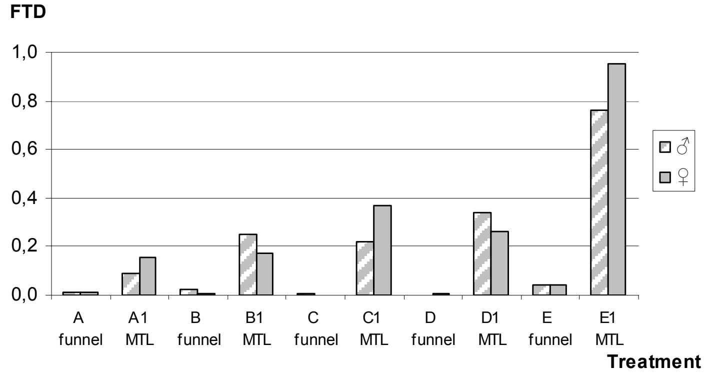

FIG. 4. Number of flies, males and females, captured per trap and per day (FTD) in Patch Stations.

3.4. Yellow Sphere and Patch Stations

In this study (FIG. 5), there was a very low capture (< 0.1 FTD) in all treatments. However, treatment (D) Funnel + TMA + AA + Imidachloprid was the most effective of FIG.5. All flies captured were males.

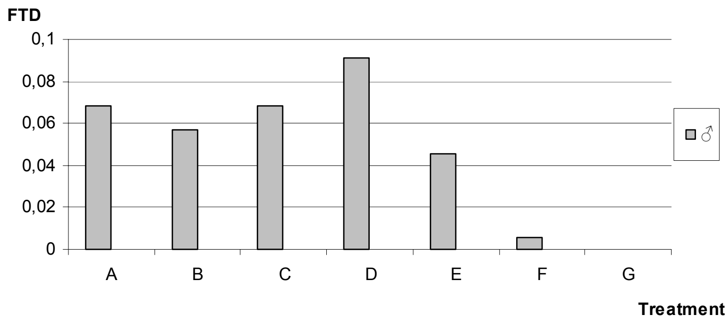

FIG. 5. Number of flies captured per trap and per day (FTD) in Yellow Sphere and Patch Stations.

4. CONCLUSIONS

With this experiments we have verified that the attractiveness of these materials used in bait station preparations are low when compared with regular attractants. However, the treatment using GS-Patch (Study 2) and Solbait + model 20 (Study 3) has shown very interesting results in total captures and number of female captures. These materials are easy to handle allowing its use in huge quantities.

ACKNOWLEDGEMENTS

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DEVELOPMENT OF IMPROVED ATTRACTANTS AND THEIR INTEGRATION INTO FRUIT FLY SIT MANAGEMENT PROGRAMMES: FINAL REPORT FOR THE PERIOD 2001–2005

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Abastract

Standard experiments on *B. zonata* and *Ceratitis* spp. were conducted during Phase 1 (2001), Phase 2 (2003) and Phase 4 (2005). In 2001, only *C. rosa* was present in the selected site. In 2003 and 2005, as populations of *B. zonata* and *Ceratitis rosa* were mixed in the experimental site, we could obtain results on the response of both species to the two series of tested attractants. Standard experiments on *B. cucurbitae* where conducted during Phase 1 (2001) and Phase 4 (2004). For all trials, experimental plots were chosen according to selection criteria which were the absence of insecticide treatments, the presence of a suitable fruit fly population, and the uniformity of habitat. All experiments were conducted following the standard protocols, except when otherwise mentioned. Data were analysed using ANOVA followed by Tukey's tests, after logarithmic transformation ($y = \log(x + 1)$). On the Natal fruit fly results in terms of most effective trapping system were not the same among years. In 2001 standard experiment, using 3C and comparing various retention systems or insecticides, showed that 3C + water + Triton was significantly more attractive than the other treatments for both sexes. In the 2003 standard experiment, significantly more females were caught with NuLure than with any other treatment. In the 2005 standard experiment, the highest catches of females were obtained with Torula Yeast. On the peach fruit fly, *B. zonata*, in the 2003 standard experiment, the highest quantity of females was caught with the higher dose of Ammonium Acetate (2AA), which attracted significantly more females than the lower dose (1/2 AA) or any other treatment. As to the melon fly, *B. cucurbitae*, the 2001 standard experiment showed that Torula Yeast and AA were significantly more attractive than the other attractants for both sexes. However, AA appeared more selective than Torula Yeast, which caught significantly more non-target insects than all other treatments. In the 2004 standard experiment, the highest catches of females were observed in the Multilure traps baited with 3C. The standard experiments conducted during the programme improved our knowledge of the effectiveness of various attractants for both sexes of the Natal fruit fly, *C. rosa*, the Peach fruit fly, *B. zonata* and the Melon fly, *B. cucurbitae*.

1. INTRODUCTION

During this Co-ordinated Research Project, research was carried out in CIRAD Réunion to improve the efficiency of trapping systems for females of local fruit flies. These include *Bactrocera* spp. (*Bactrocera zonata* and *Bactrocera cucurbitae*) as well as some *Ceratitis* spp. (mainly *Ceratitis rosa*). In this final report for the whole programme, we will summarize the main results obtained from research carried out from 2000 to May 2005.

2. MATERIALS AND METHODS

2.1. Standard Experiments

During the project, standard experiments were conducted on:

- the peach fruit fly, *Bactrocera zonata* and / or *Ceratitis* spp. which sometimes develop mixed populations in orchards in Reunion Island
- the melon fly, *Bactrocera cucurbitae*, a major pest of cucurbits in the island.

Standard experiments on *B. zonata* / *Ceratitis* spp. were conducted during Phase 1 (2001), Phase 2 (2003) and Phase 4 (2005). In 2001, only *C. rosa* was present in the selected site. In 2003 and 2005, as populations of *B. zonata* and *Ceratitis rosa* were mixed in the experimental site, we could obtain results on the response of both species to the two series of tested attractants. Standard experiments on *B. cucurbitae* where conducted during Phase 1 (2001) and Phase 4 (2004).

For all trials, experimental plots were chosen according to selection criteria which were the absence of insecticide treatments, the presence of a suitable fruit fly population, and the uniformity of habitat. All experiments were conducted following the standard protocols, except when otherwise mentioned. Data were analysed using ANOVA followed by Tukey's tests, after logarithmic transformation ($y = \log(x + 1)$).

2.1.1. Trapping systems for Bactrocera zonata and Ceratitis spp.

2.1.1.1. Trial 2001

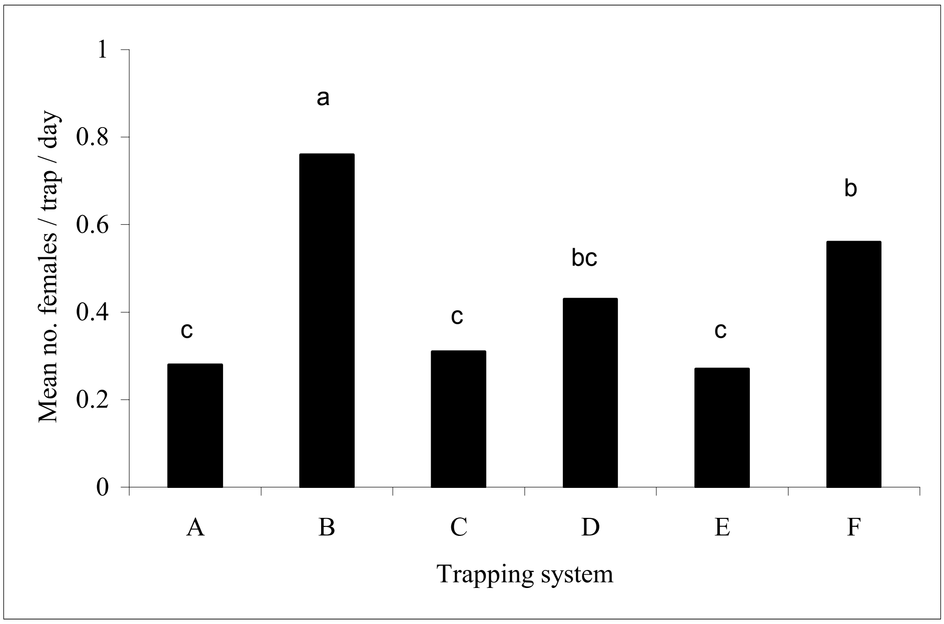
During the Phase 1 of the programme, a Citrus plot was selected in Les Lianes in the south of the island, at an altitude of 750 m a.s.l.. The plot had a surface of one hectare with Citrus 15 years-old, planted at a density of 5m x 5m. It consisted in a mixture of 3 varieties: tangerine (*Citrus reticulata* Blanco var.Zanzibar), clementine (*C. reticulata* Blanco), and tangor (*C. reticulata* Blanco x *C. sinensis* (L.) Osbeck). The plot was surrounded by natural strands of Chinese guava (*Psidium cattleianum* Sabine), sugarcane (*Saccharum officinarum* L.) and other Citrus orchards. The trial on *C. rosa* was conducted from June 28th to August 23rd 2001.

Traps were placed at a height of ca. 1.20 m within tree canopies. Due to the limited surface of the orchard, the distance between traps had to be reduced to ca. 10 m instead of the 25 m planned in the standard protocol. The experimental design consisted in randomized blocks with permutation of traps twice a week. The disposition of blocks was chosen so that they were constituted of trees of about the same size.

The six trapping systems compared were: A) NuLure + borax; B) 3C (Ammonium Acetate (AA) + Putrescine (PT) + Trimethylamine (TMA)) + water + Triton; C) 3C + Propylene Glycol; D) 3C + Dichlorvos; E) 3C + Deltamethrinee; and (F) 3C + sticky insert. As no meteorological station was available on the site of Les Lianes, temperature data could be collected from a Meteo-France station situated 4 km east of the orchard, at an altitude of 1050 m a.s.l. On site temperature data could be estimated using of positive correction of 0.75°C / 100 m that is 2.25°C.

All fruit fly catches recorded during this trial corresponded to *C. rosa*, as could be expected given the altitude of the site. Treatment B (3C + water + Triton) was significantly more attractive than the other treatments, in terms of total catches. Treatments including an insecticide (Dichlorvos or Deltamethrinee) gave significantly less catches, the one with Dichlorvos giving somewhat better results. The trapping system with NuLure was significantly less attractive than the 3C associated with a sticky insert. Tukey's test indicated that female catches were significantly more abundant than male catches. A comparison of treatments analysing separately male and female catches confirmed that 3C + water + Triton was significantly more attractive than the other treatments, for both males and females of *C. rosa* (FIG.1).

Regarding *C. rosa* trapping systems, the better attractiveness of 3C when associated with a water solution (water + Triton), vs Propylene Glycol may be due to a repulsive effect of Propylene Glycol and / or to the limitation of water evaporation by the presence of this compound. When the different types of dry traps are compared, the presence of insecticide in the trapping system seems to have a repulsive effect in the case of Deltamethrinee (traps with Deltamethrinee are significantly less attractive than those with sticky insert). The repulsive effect of Dichlorvos seems less marked as catches in traps with this insecticide are not significantly inferior than with sticky insert. The better attractiveness of the trapping system with water and Triton, compared with sticky insert, is probably due to a favourable effect of the presence of solution (increase of relative humidity around the trap) on *C. rosa* catches, as both trapping systems can be considered as presenting similar odours.



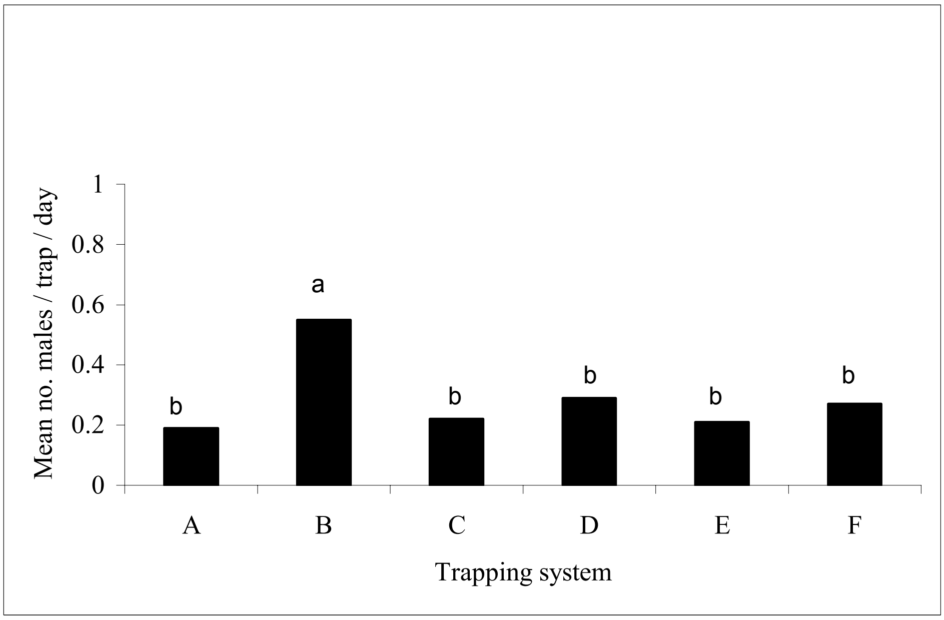


FIG. 1: Standard experiment 2001: Mean number of Ceratitis rosa *caught in different trapping systems in a citrus Plot in Les Lianes (2001). 1A: females of* C. rosa*; 1B: males* of C. rosa. *(A = NuLure (9%) + borax (3%); B = 3C (+ water + Triton); C = 3C + Propylene Glycol; D = 3C + Dichlorvos; E = 3C + Deltamethrinee; F = 3C + sticky inser).*

2.1.1.2. Trial 2003

The objective of the standard experiment conducted during Phase 2 was to assess the relative effectiveness of 7 attractants for both sexes of the peach fruit fly : NuLure, Ammonium Acetate (AA, 1/2 or 2 dispensers), Di-Ammonium Phosphate (Di-AP), Ammonium Sulphate (AS), AA+PT+TMA (3C) and Torula Yeast. The experiment was conducted in a mango orchard situated at medium altitude in the south of the island, at the beginning of 2003. The methodology was as initially planned, except for the distance between traps that was lower than planned.

Interestingly, for *B. zonata*, the highest quantity of females was caught with the higher dose of 2AA, which attracted significantly more females than the lower dose (1/2 AA) or any other treatment (FIG. 2A). The lower dose was not significantly different from NuLure or 3C, but significantly more attractive than Torula Yeast. The poorest results were obtained with AS and Di-AP, the last one attracting very few females. For the males of peach fruit fly, few significant differences appeared between the treatments (FIG. 2B). In particular, no difference appeared between the two doses of AA. The lower dose caught significantly more males than AS, Torula Yeast or Di-AP.

For *Ceratitis rosa*, significantly more females were caught with NuLure than with any other treatment (FIG. 2C). No difference was observed between the two doses of AA, the 3C or Torula Yeast, which were all more attractive than AS and Di-AP (the least attractive). For males of the Natal Fruit Fly, the highest catches were observed with 3C, though no significant difference was observed between 3C, NuLure and the higher dose of AA (FIG. 2D). 3C was significantly more attractive than Torula Yeast. Again, the poorest results were obtained with AS and Di-AP, which were significantly less attractive than all other treatments.

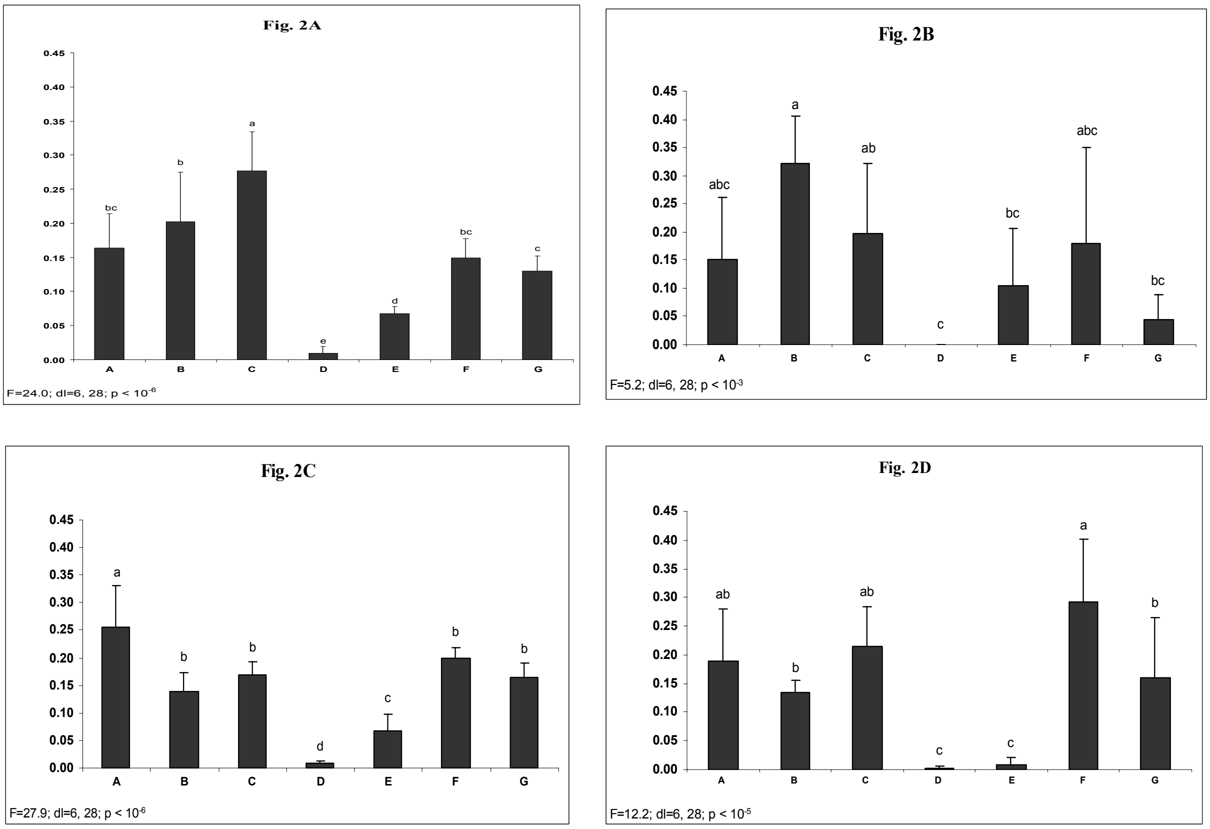
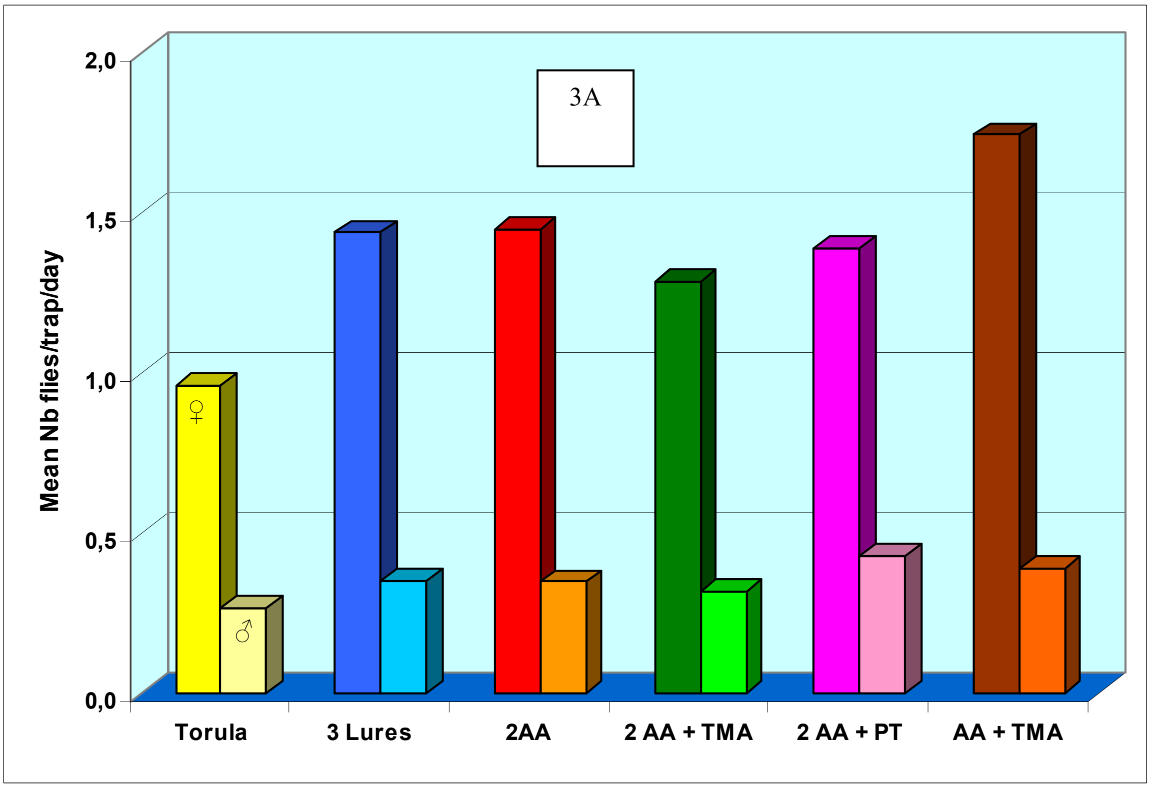


FIG. 2: Standard experiment 2003 in a mango orchard. Relative attractiveness of the various treatments for : 2A : Females of B. zonata*; 2B : Males of* B. zonata*; 2C : Females of* C. rosa*; 2D: Males of* C. rosa. *Treatments : A = NuLure 9% + borax 3%; B = 0.5 AA (+ water + Triton); C = 2 AA (+ water + Triton); D = Di-AP (+ water + Triton); E = AS (+ water + Triton); F = 3C (+ water + Triton); G = Torula Yeast.*

2.1.1.3. Trial 2005

As agreed during the 3rd Research Co-ordinated Meeting held in Fort Lauderdale, Florida, in May 2004, the main objective of the standard experiment conducted during Phase 4 was to assess the relative effectiveness of 7 attractants for both sexes of the peach fruit fly: Torula Yeast, 3C, 2AA, 2AA+TMA, 2AA+PT, Solbait, and AA+TMA. The experiment was conducted in a mango orchard, in Montvert-les-Hauts (400 m a.s.l.) during the first trimester of 2005.



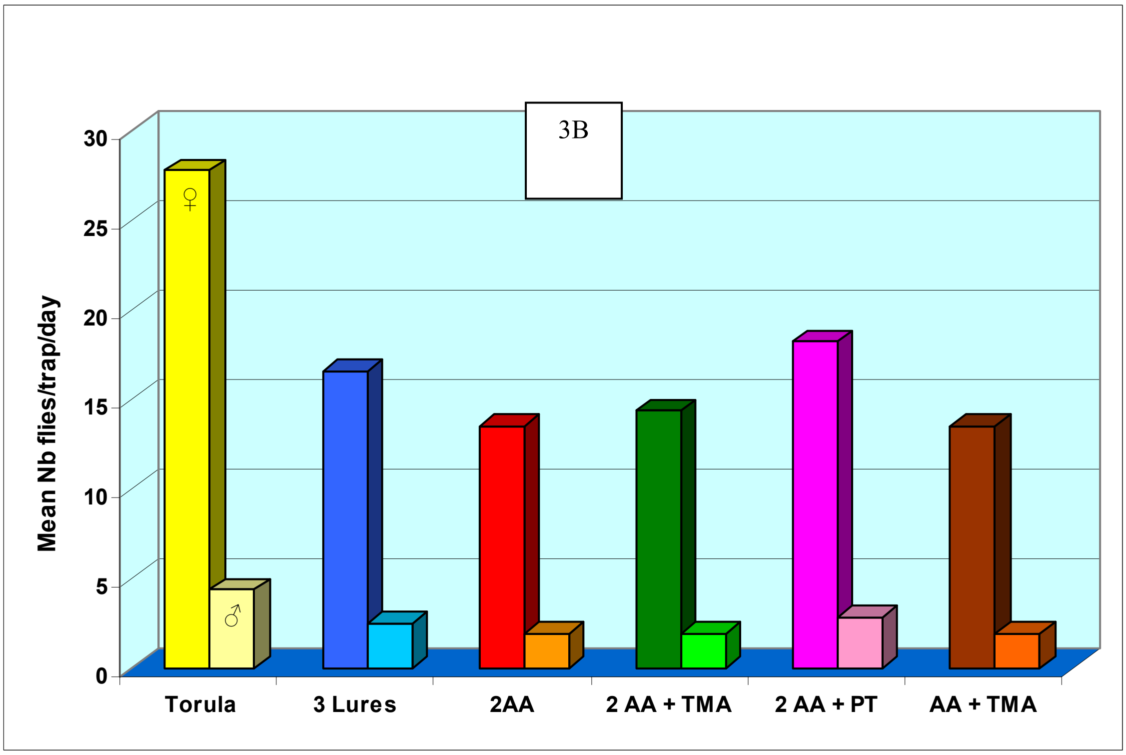


FIG. 3. Standard experiment 2005 in a mango orchard: Relative attractiveness of the various attractants in Multilure traps for: 3A: Both sexes of B. zonata*; 3B: Both sexes of* C. rosa*. Treatments: A = Torula Yeast; B = AA + TMA + PT (+ water + Triton); C = 2 AA (+ water + Triton); D = 2AA + TMA (+ water + Triton); E = 2 AA + PT (+ water + Triton); F = Solbait (solid) + water + Triton); G = AA + TMA.*

For *B. zonata*, the highest catches of females were obtained with AA + TMA and the lowest with Torula (FIG. 3A). Intermediate results were obtained with 3 lures or the three treatments including 2AA. By contrast, for *C. rosa*, the highest catches of females were obtained with Torula Yeast (FIG. 3B).

2.2. Bait stations for *Bactrocera zonata* and *Ceratitis* species

At the beginning of 2005, from February 24th to March 17th, a first replicate with the standard protocol was conducted using R. Mangan's bait stations. This experiment was conducted in the same mango orchard as for the standard experiment (Montvert-les-Hauts, 400 m a.s.l.). Our objective was to assess the relative effectiveness of 5 patch stations (treatments) for both sexes of the peach fruit fly and / or *Ceratitis* spp.: Solbait, Solbait + AA, Solbait + model 20, Solbait + model 24 and NuLure. All tested attractants were used whether in a Multilure trap or as bait stations.

The fruit fly populations were quite high on the orchard during the experiment, as indicated by the catches in Multilure traps baited with Torula Yeast that were placed in a nearby part of the orchard. Catches in the Torula Yeast traps indicated the dominance of *Ceratitis rosa*, with also the presence of *B. zonata*. Despite the high prevalence of flies in the orchard, the attractants tested gave very limited catches, whether they were placed in Multilure traps or in the bait-stations (FIG. 4). It was concluded that the 5 bait stations tested show very poor attractiveness for both sexes of *B. zonata* and *C. rosa*.

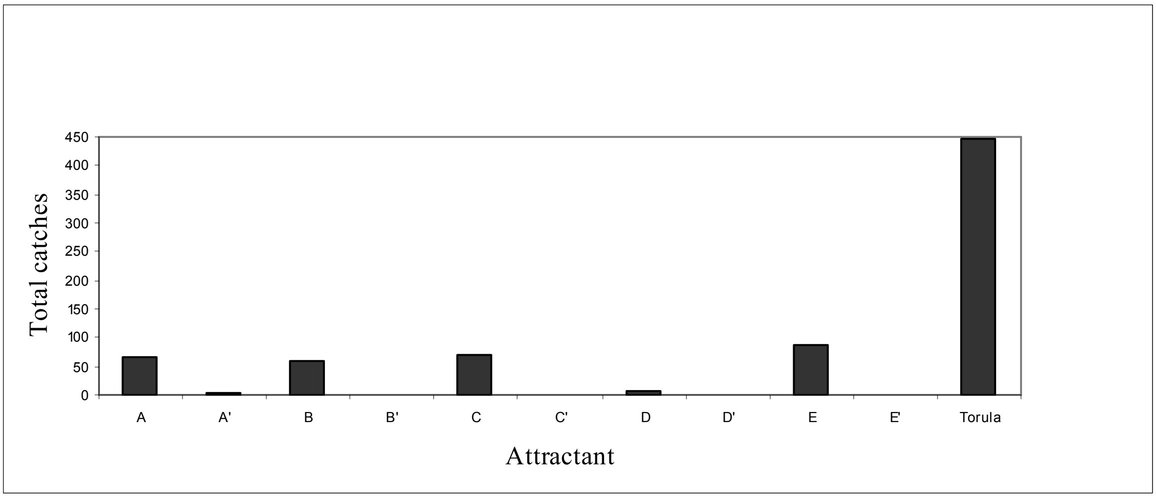


FIG. 4: Standard experiment 2005 with bait stations in a mango orchard: Relative attractiveness for Ceratitis rosa *females of various attractants placed in Multilure traps or bait stations. Treatment: A = Solbait; B = Solbait + AA; C = Solbait +Model 20; D = Solbait +Model 24; E = NuLure. A, B, C, D, and E: catches in Multilure traps. A', B', C', D' and E': catches in bait stations.*

2.3. Trapping systems for *Bactrocera cucurbitae*

2.3.1. Trial 2001

A cucurbit plot was settled in the CIRAD-Flhor Station of Bassin Plat, situated in the south of the island, at an altitude of 140 m a.s.l. The plot was bordered on the north-west and south-west sides by hedges of non-host plants, notably *Leucaena leucocephala* Lam. On the north-east side a row of *Acacia* sp. was present, and on the south-east side a mango (*Mangifera indica* L.) orchard. Courgettes (*Cucurbita pepo* L.) were planted on the plot from January 10th to April 5th 2001. The plot consisted in double-rows of courgettes, separated by non-planted bands of 10 m width.

Within the plot, the traps were hung on metallic poles, so that they were situated just above the foliage level. Due to limited surface of the plot, the traps couldn't be separated by the distance recommended in the standard protocol and were placed along the double-rows, separated by a distance of ca. 10 m. For this trial, the experimental design was a Latin Square with horizontal permutation of rows.

The 6 trapping systems compared in this experiment were: (A) NuLure + borax; (B) Ammonium Bicarbonate (AB) (+ water + Triton); (C) AB + Dichlorvos; (D) Torula Yeast (+ water + Triton); (E) Ammonium Phosphate (AP)(+ water + Triton); (F) Ammonium Acetate (AA)(+ water + Triton). Meteorological data for the Bassin Plat Station were collected from the meteo station on Ligne Paradis CIRAD Station, situated at a 300 m distance from Bassin Plat.

Trapping systems D and F (Torula and AA) were significantly more attractive than the others in terms of total *B. cucurbitae* catches, but were not significantly different between them (Fig. 5). Treatments C and E (AB associated with Dichlorvos and AP) gave significantly lower catches compared to other treatments. The AB dispenser was significantly more attractive when associated with a water solution (B) than with Dichlorvos (C). If we consider the total number of trapped insects (*B. cucurbitae* plus the other species), Torula Yeast caught significantly more insects than all other treatments. This attractant indeed appears less selective than AA for the capture of *B. cucurbitae*. Tukey's test indicated that female catches were significantly more abundant than male catches. A comparison of treatments analysing separately male and female catches confirmed that Torula Yeast and AA are significantly more attractive than the others for both males and females of *B. cucurbitae* (FIG. 5). Also, a significant negative correlation was found between number of males caught and temperature ($r = -0{,}3473$; $P = 0{,}0005$).

Among trapping systems for *B. cucurbitae*, AA and Torula Yeast appeared the most attractive for both males and females, but the former proved to be more selective. When AB was tested in solution (with water and Triton) or associated with DDVP, the best results were obtained with the solution, which might indicate that Dichlorvos has a repulsive effect for both sexes of melon fly, and / or that the increased attractiveness may be due to the presence of a solution, possibly by an increase in relative humidity around the trap. The negative correlation observed between temperature and male catches may indicate that male flight activity or response to attractants is affected by high temperatures.

2.3.2. Trial 2004

Due to low fly populations, the standard experiment on *B. cucurbitae*, that was planned during phase 3, had to be delayed and was conducted from June to August 2004. The objective of the experiment was to assess the relative effectiveness of 7 attractants (treatments) for both sexes of the melon fly : NuLure, AA (1/2 or 2 dispensers), Di-AP, AS, 3C and Torula Yeast. The experiment was conducted in a zucchini plot situated at Bassin Plat, at low altitude in the south of the island.

During most of the month of July, low populations of *B. cucurbitae* were observed on the plot. An increase was observed at the end of July and the catches showed a peak during the first half of August. The highest catches of females of *B. cucurbitae* were observed in the Multilure traps baited with 3C, while an important level of catches was also noticed with NuLure, Torula Yeast and ½ AA. The catches of females were significantly higher with 3C than with Di-AP and AS.

A more or less similar trend was observed for males, with the highest catches recorded in the Multilure traps baited with Torula Yeast and 1/2 AA, and a good level of catches with NuLure and 3C. These four attractants caught significantly more males than Di-AP.

3. SIDE EXPERIMENTS

Among various side experiments that were initially planned, we finally concentrated our studies on the relative attractiveness for *B. cucurbitae* of various potential food baits that could be used in bait-sprays. These experiments were conducted in field-cages. We also examined the influence of pH on the attractiveness of the baits for both sexes of the melon fly.

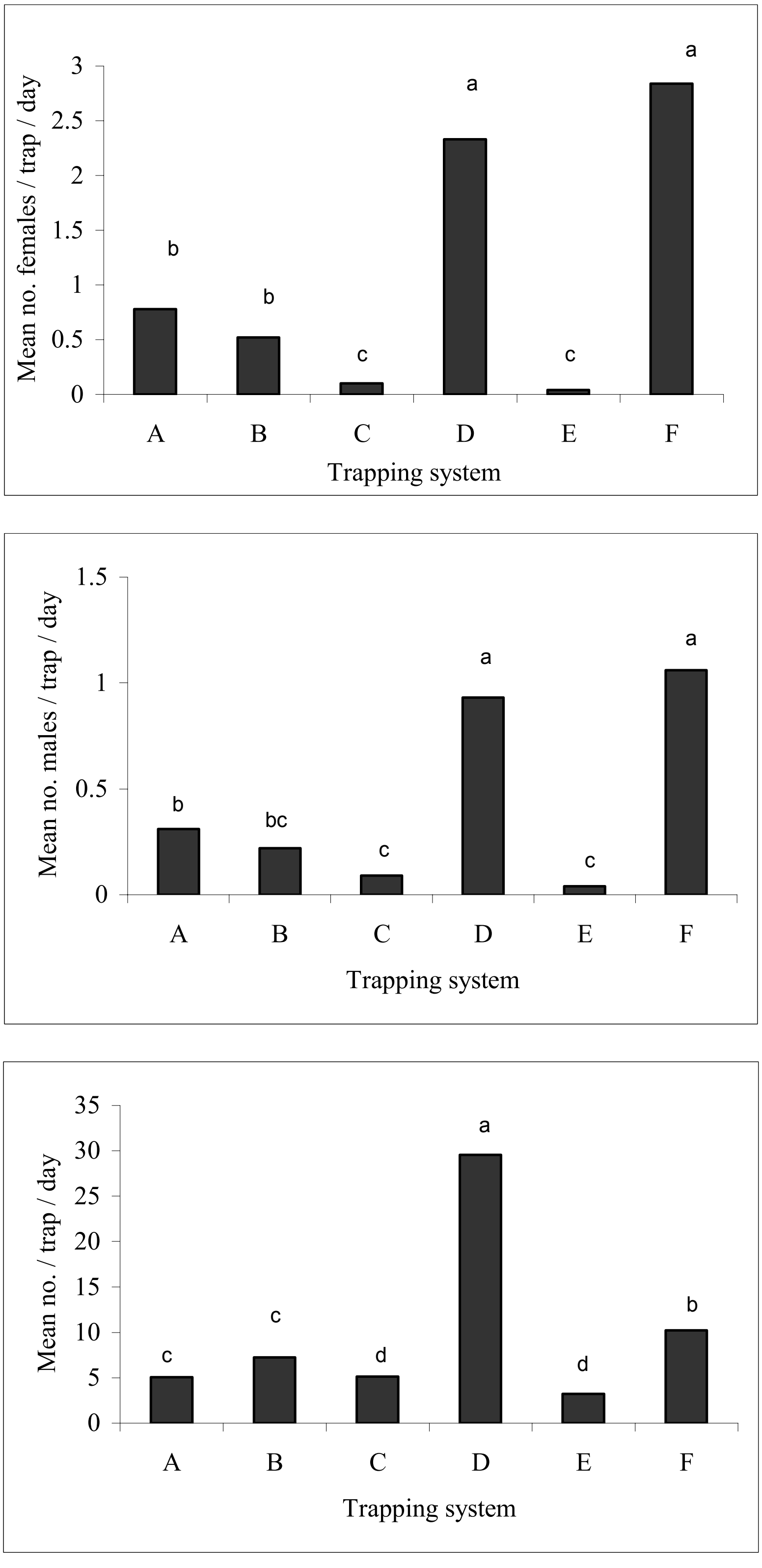
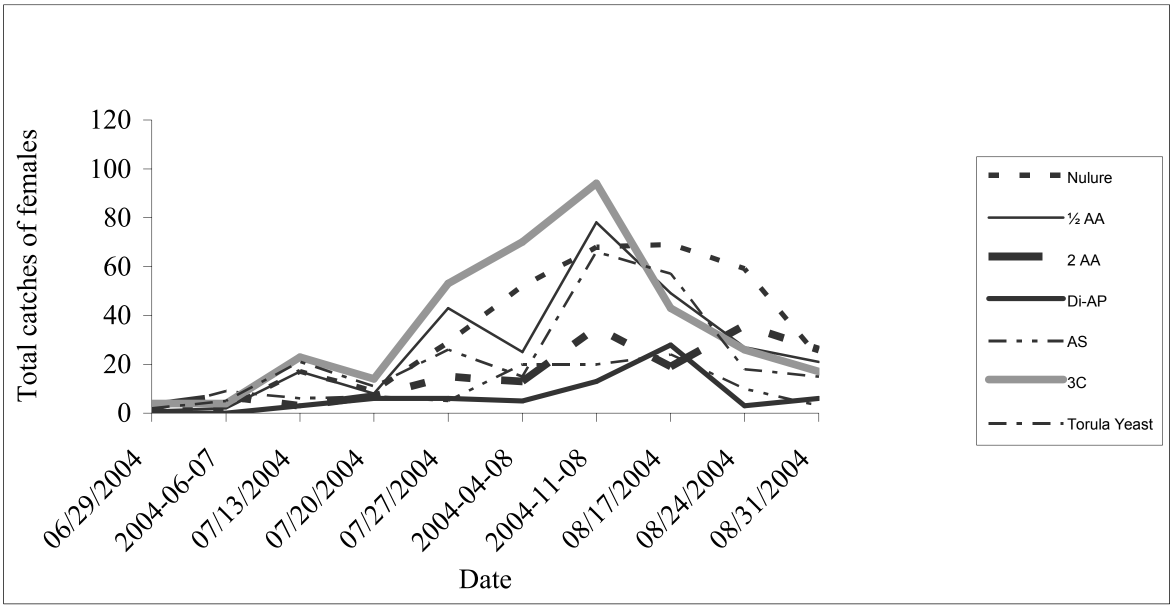


*FIG. 5: Standard experiment 2001: Mean number of insects caught in different trapping systems in a zucchini (*Cucurbita pepo *L.) plot. 5A: females* of Bactrocera cucurbitae*; 5B: males* of B. cucurbitae*; 5C: both sexes of* B. cucurbitae *and other insects. Trial 2001. A = NuLure (9%) + borax (3%); B = AB (+ water + Triton); C = AB + Dichlorvos; D = Torula Yeast (+ water + Triton); E = AP (+ water + Triton); F = AA (+ water + Triton).*



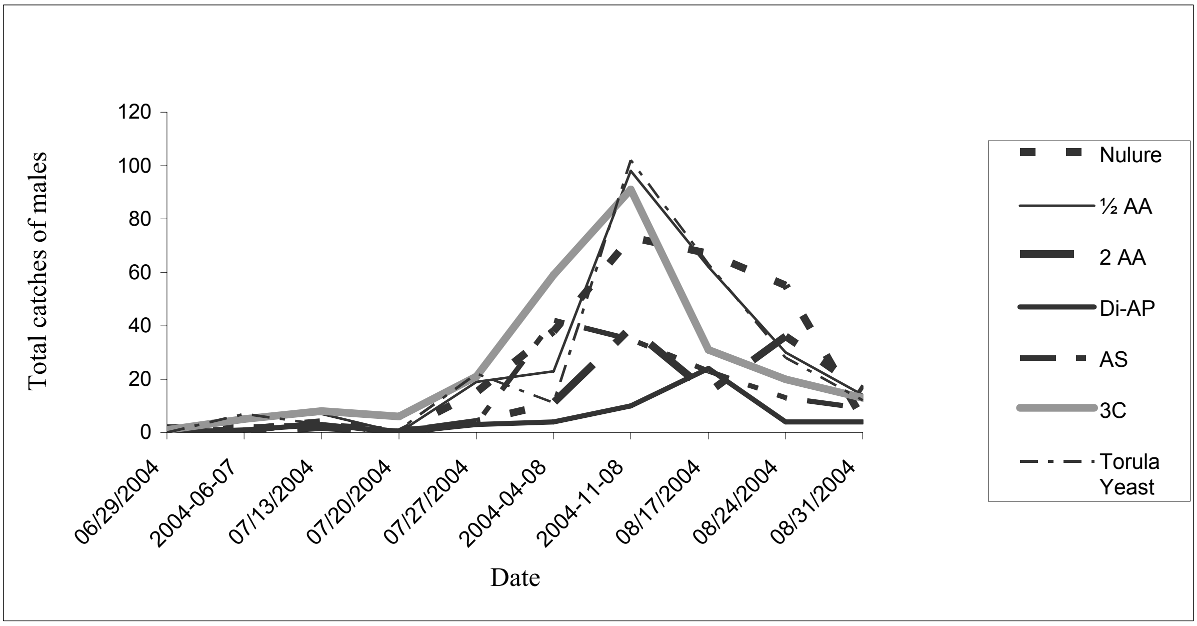


FIG. 6. Standard experiment 2004 in a zucchini plot : Relative attractiveness of the various attractants in Multilure traps for : 6A : Females of Bactrocera cucurbitae*; 6B : Males of* B. cucurbitae*; Treatments : A = NuLure (9%) + borax (3%); B = ½ AA (+ water + Triton); C = 2 AA (+ water + Triton); D = Di-AP (+ water + Triton); E = AS (+ water + Triton); F = 3C (+ water + Triton); G = Torula Yeast.*

Regarding *Ceratitis* spp., an experiment was conducted to compare the relative efficiency of two trapping systems (MLT vs Tephri-trap) using the 3C as the attractant.

3.1. Improvement of trapping systems for *Ceratitis* spp.

During 2003, an experiment was conducted to compare the relative efficiency of two trapping systems (MLT vs Tephri-Trap) for *Ceratitis* spp., using the “3C” as the attractant. This experiment was conducted on the CIRAD station of Bassin Martin, situated at 350 m a.s.l. in the south of the island. In the conditions of our experiment, when baited with 3C, the Tephri-trap appeared to be more effective than the MLT for trapping both sexes of *C. rosa* (FIG. 7).

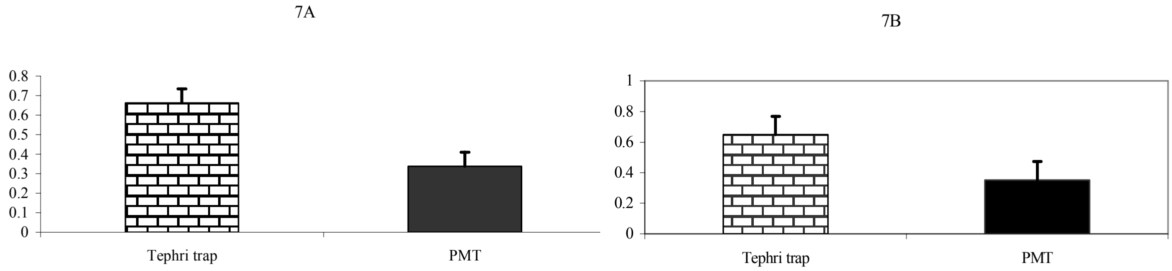


FIG. 7. Mean percentage of Ceratitis rosa *adults caught with the two trapping systems baited with 3C. 7A: females; 7B: males. Bassin Martin, 2003.*

3.2. Comparison of the attractiveness of various food attractants and their concentration for *B. cucurbitae*

The results of these experiments have been published [4] and we will simply summarize here the main findings. The relative attractiveness of six commercially available protein hydrolysates and the influence of their concentration were evaluated in field-cages by a release-capture method of lab-reared melon fly adults. Buminal, Corn Steepwater, Hym-Lure, Pinnacle, NuLure and SolBait were tested for both sexes of the fly. The tested products exhibited clear differences in attractiveness (FIG. 8). SolBait was the most effective protein hydrolysate. Pinnacle and Corn Steepwater also gave promising results. A general tendency for an increase in effectiveness with increasing concentration within the range 0.5 to 10 % was shown. This study can help selecting more effective attractants for use in bait-sprays to control melon fly thus reducing the intensive use of insecticides currently practised in Reunion Island and enabling the development of Integrated Pest Management (IPM) methods for cucurbit crops.

3.3. Influence of pH on bait attractiveness for *B. cucurbitae*

Borax may improve the attractiveness of protein baits in traps for various Tephritidae (Bateman and Morton 1981, Heath et al. 1994) but to our knowledge no studies have been carried out on the influence of borax on bait attractiveness for *B. cucurbitae.* Modification of pH, most frequently alkalization, is also known to influence the attractiveness of the baits (Bateman and Morton 1981, Flath et al. 1989, Epsky et al. 1994).

In this study, the influence of adding borax to Buminal or NuLure on the attractiveness for the melon fly was evaluated. The influence on the attractiveness for the melon fly of modifying the pH of Buminal, NuLure and standard Torula Yeast solutions was also examined. We used a release-recapture method in field cages similar to that used for the comparison of food attractants (cf. 2.2). These results have been published (*J. Econ. Entomol*., 2004, 97 (3): 1137-1141) and will only be summarized here.

Each day of the experiment, four cages were used simultaneously: two for females and two for males. In each cage 250 adults were released at 0700 hours local time to allow flies to disperse. For each replicate, at 0800 hours, four traps with the different attractants were placed in the cage in random order and every 2 h a circular permutation (quarter turn) of the traps position was carried out to reduce any influence of trap position. At 1600, the flies collected from each trap were counted and those remaining in the cage were recaptured to allow for another trial the day after. A trial was run during two days which gave four replicates (a replicate = one cage / day) by sex for a complete experiment. Fresh baits and naive flies were used at the beginning of each replicate. Percentages of the solutions are expressed in volume by volume except for borax for which they are expressed in weight.

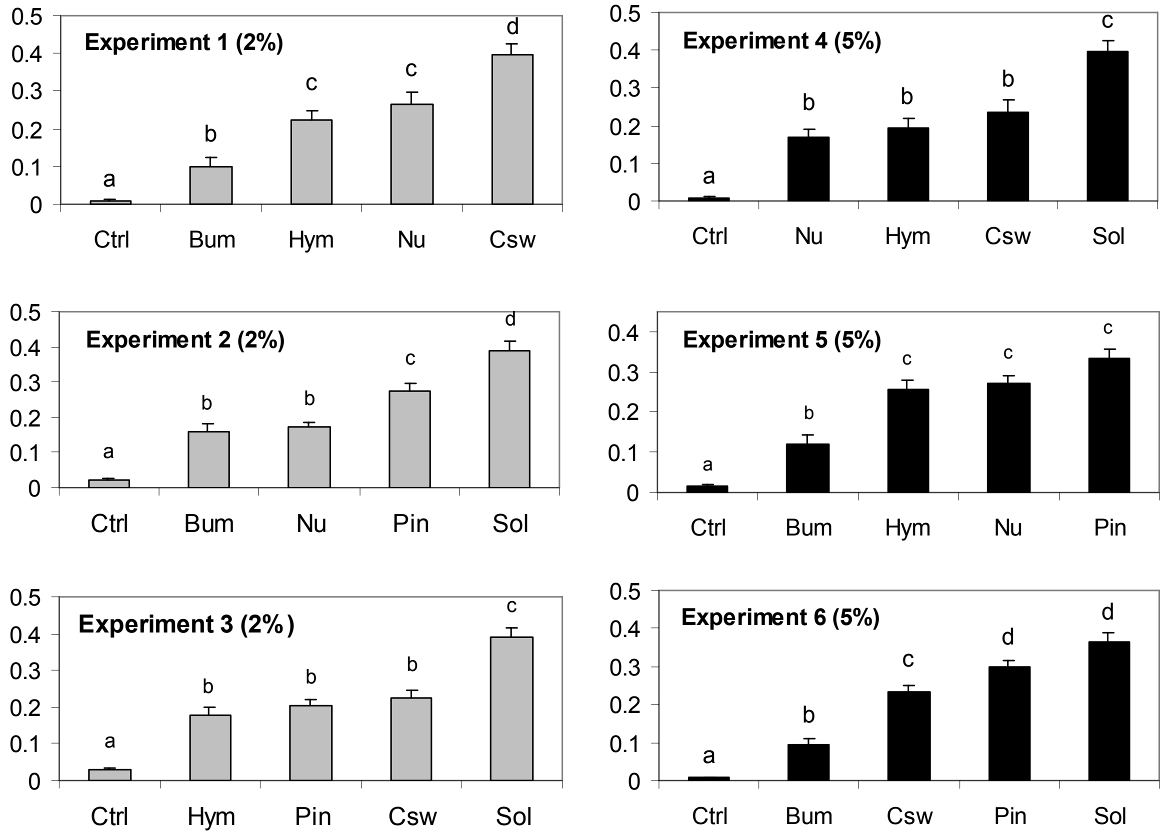


FIG.8. Percentage of melon flies (mean of males and females (±SE)) captured in each Dome trap with water (Ctrl); Buminal (Bum); NuLure (Nu); Hym-Lure (Hym); Pinnacle (Pin); Corn Steepwater (Csw) and SolBait (Sol). Bars headed by the same letter within a graph are not significantly different (Tukey's test mean separation on 2 arcsin (sqrt x) transformed data; non transformed means presented).

In choice trials, the relative attractiveness of Buminal with 0, 1, 5 and 10% borax was compared in experiment 1, whereas the relative attractiveness of NuLure (5%) with 0, 1, 5 and 10% borax was compared in experiment 2.

As borax is known to affect the pH of the solutions we investigated whether its effect on the attractiveness was only due to pH modification. Buminal (5%) and NuLure (5%) were alkalized with sodium hydroxide in experiments 3 and 4 respectively, to reach target pH of 6-7-8-9 and 4-6-8-10 respectively. In experiments 5 and 6, Torula Yeast was alkalized with sodium hydroxide to reach target pH of 9-9.5-10-10.5 and 10.5-11-11.5-12 respectively. Buminal (5%) and Torula Yeast (Agrisense, Mid Glamorgan, UK) (2 pellets/ 200ml) were acidified with nitric acid in experiments 7 and 8 respectively, to reach target pH of 6-5-4-3 and 9-7-5-3 respectively. No attempt was done to acidify NuLure, as the initial pH of this product was already very low (pH 3.53). Previous curves of volume of nitric acid or sodium hydroxide plotted against pH were prepared in preliminary trials in order to determine the quantity of nitric acid or sodium hydroxide needed to reach a particular pH value.

As our purpose was to compare the relative effectiveness of the products, the data analyzed for each cage were the total number of flies caught in one trap during one day divided by the total number of flies caught in all traps during the same day. Data were transformed by arcsine (square root x) to stabilize the variance prior to analysis. They were analyzed by a three-way analysis of variance (ANOVA). When the F-value was significant ($P < 0.05$), a Tukey's mean separation test was used.

For all experiments, neither replicate nor sex nor the three first order interactions had any significant influence on the results. Conversely, the factor ‘products’ always showed a significant influence on the results (at least between treatments and control). Because the relative attractiveness of each product was the same for each replicate and for both sexes, the mean percentages of capture were only compared among products. Mean percentage of recaptured flies in the different experiments was 54±17 % for males and 58±19 % for females.

Adding borax to protein hydrolysates Buminal and NuLure strongly reduced their attractiveness for B. cucurbitae (FIG. 9A and B). Attractiveness of Buminal with 1, 5 or 10% borax was not significantly different from that of water. Adding 1, 5, or 10 % borax to NuLure was less attractive than NuLure alone. However, NuLure with borax was significantly more attractive than water. NuLure with 10% borax was less attractive than with 5% borax.

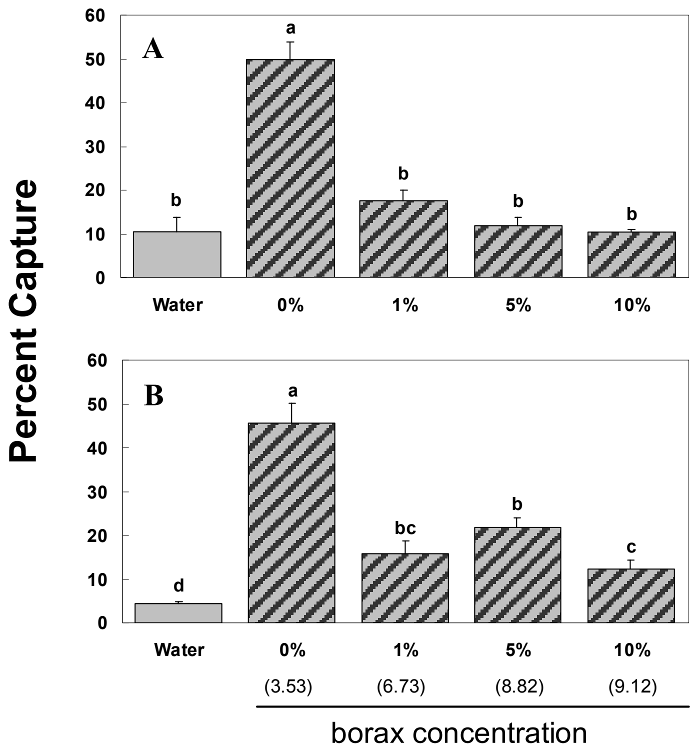


FIG. 9. Mean percentage of male and female Bactrocera cucurbitae *captured in McPhail traps baited with protein hydrolysates and various concentrations of borax: A) Buminal 5% + borax (experiment 1); B) NuLure 5% + borax (experiment 2). pH values of bait mixture are indicated in parenthesis under borax concentration values. Bars headed by the same letter within a graph are not significantly different (Tukey’s mean separation test on arcsin (sqrt x) transformed data, non transformed means presented). Bars without hatches are water controls.*

Alkalization of buminal reduced its effectiveness (FIG. 10a). There was an insignificant reduction in attractiveness between the buminal ph 6 (original bait) and the buminal ph 7. The decrease in attractiveness was more drastic when ph value increased to ph8 and ph9; at these two ph values, the buminal solutions were not significantly more attractive than the control. Unlike buminal, the attractiveness of nulure did not decline with increasing ph (FIG. 10b). There was no significant difference between original (ph 4) and alkalized nulure.

Results of experiment 5 show that torula yeast alkalized to a certain extent is more attractive for *b. Cucurbitae* than standard torula yeast (FIG. 10c). Torula yeast at pH 10.5 was significantly more attractive than standard torula yeast at pH9 (responsible for 28% of recaptured flies compared to 17%). However a further increase of the ph of the torula yeast solution, induces no further improvement of its attractiveness. In experiment 6, we found no significant difference among several Torula Yeast solutions at ph 10.5, 11, 11.5 and 12 (FIG. 10d).

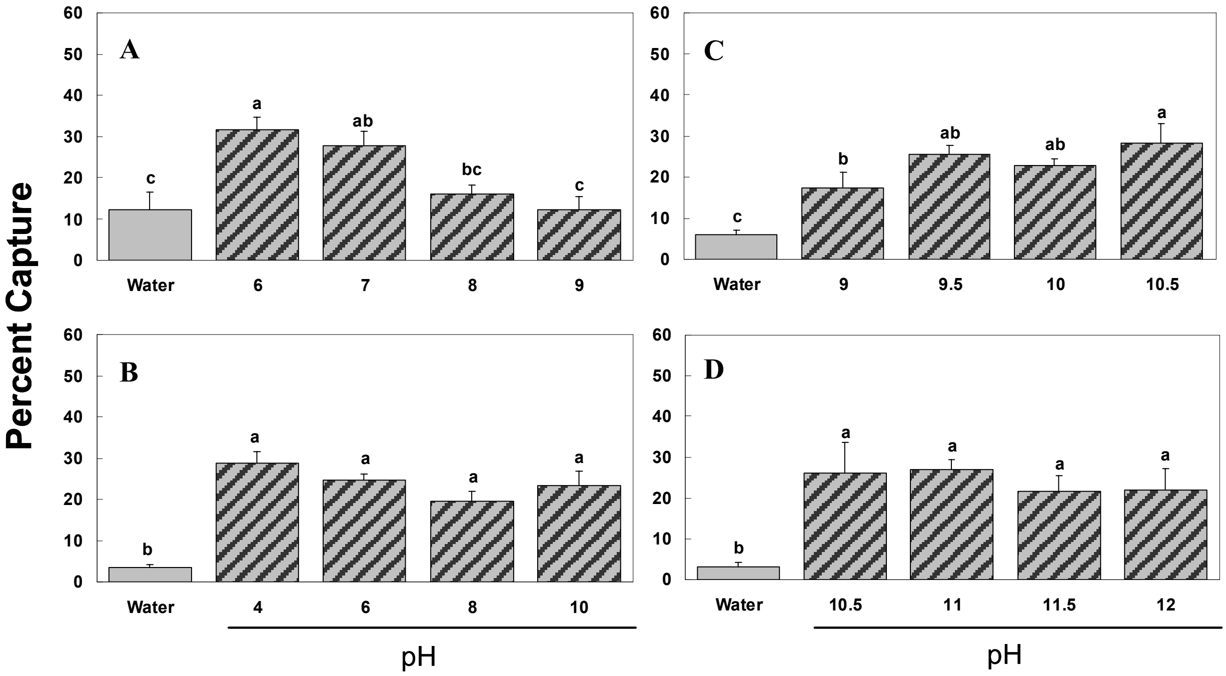


FIG. 10. Mean percentage of male and female Bactrocera cucurbitae *captured in McPhail traps baited with food attractants alkalized to reach various pH values: A) Buminal 5% + NaOH (experiment 3); B) NuLure + NaOH (experiment 4); C) Torula + NaOH (experiment 5); D) Torula + NaOH (experiment 6). Bars headed by the same letter within a graph are not significantly different (Tukey's mean separation test on arcsin (sqrt x) transformed data, non transformed means presented). Bars without hatches are water controls.*

Modification of the ph of a buminal 5% solution from ph6 to ph3 doubled its attractiveness for *B. cucurbitae* (FIG. 11a). Buminal at ph3 was significantly more attractive than all other treatments compared during experiment 7. On the other hand, results of experiment 8 showed that acidified Torula Yeast became less attractive than the standard solution (pH9), the three acidified torula (pH7, pH5 and pH3) being not significantly different among them (FIG. 11b).

Our study shows that the addition of borax decreases the attractiveness of some commercial protein hydrolysates to *B. cucurbitae*. Similarly Lopez-d and Hernandez Becerill (1967) demonstrated in a field experiment that the attractiveness of pib 7 to *Anastrepha ludens* (loew) was lowered when borax was added to the solutions. In contrast, Heath *et al*. (1994) showed that adding borax (1 to 10%) to nulure solutions increased their attractiveness for *C. capitata* (wiedemann) up to the highest concentration tested (10%). For *A. ludens*, these authors showed that the optimal concentration of borax when added to nulure was 3% and that the attractiveness subsequently decreased with increasing concentrations up to 10%. The influence of borax on attractiveness of protein hydrolysate solutions appears to vary depending on the tephritid species (or at least on the subfamily) studied.

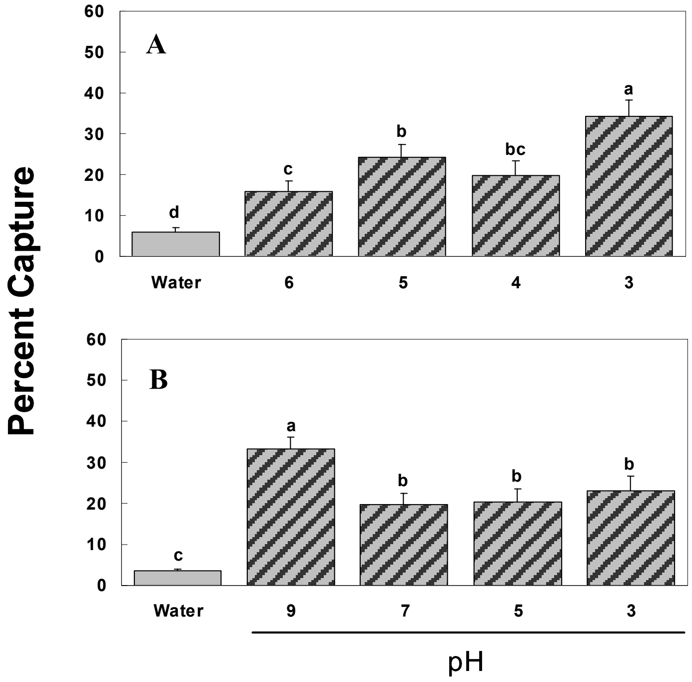


FIG. 11. Mean percentage of male and female Bactrocera cucurbitae *captured in McPhail traps baited with food attractants acidified to reach various pH values : A) Buminal 5% + HNO_3 (experiment 7); B) Torula + HNO_3 (experiment 8). Bars headed by the same letter within a graph are not significantly different (Tukey's mean separation test on arcsin (sqrt x) transformed data, non transformed means presented). Bars without hatches are water controls.*

This result may have important consequences on trapping results as borax is frequently added in traps during fruit fly monitoring or population dynamic studies to prevent protein hydrolysates from decaying and also reduces the capture of other insects (Lopez and Hernandez Becerill 1967). When borax is added to the solutions, populations of *B. cucurbitae* might be underevaluated compared with other tephritid species that are not repelled by this product.

The pH of protein hydrolysates increases with raising borax concentration. The lower attractiveness of the protein hydrolysates for *B. cucurbitae* when borax is added is probably not only due to alkalization, as adding sodium hydroxide to NuLure does not reduce its attractiveness. The final pH of an attractant may be important for its attractiveness but the product with which we modify the solution may have its own effect especially when added in large quantity.

Several studies on *Anastrepha striata* Shiner (McPhail 1939), *Bactrocera tryoni* (Froggatt) (Bateman and Morton 1981) and *Anastrepha suspensa* (Loew) (Sharp 1987) have shown that the attractiveness of different enzymatic hydrolysates for these species can be improved by increasing the pH. Mazor et al. (1987) studied the attractiveness of alkalized Nasiman (a protein hydrolysate from Israel) and Buminal for *Ceratitis capitata* (Wiedemann). The attractiveness increased with the pH of the solutions up to a certain limit (pH 8.5 for both Nasiman and Buminal), while further increase of pH decreased the attractiveness of the solutions. Our results with Buminal show that *B. cucurbitae* behaves differently from *C. capitata* in this respect though the attractiveness of Torula Yeast for melon fly was improved by alkalization up to pH 10.5.

Bactrocera cucurbitae shows opposite responses to acidification of Buminal or Torula. The changes of attractiveness for *B. cucurbitae* with modifying pH were quite different when these two products - a yeast and a protein hydrolysate - were used which is not surprising since they probably differ greatly in their chemical composition. Determining better attractive mixtures, would require a definition of an optimum pH for each species and for each bait.

The pH of an attractant - and hence its attractiveness for a given fruit fly - will often be naturally modified after several days in a trap. Heath et al. (1994) showed that the pH of a NuLure + 1% borax solution could considerably increase after seven days of field use. This could have an effect in certain studies realized on a long period in which the traps are exposed for one (Epsky *et al*. 1993, Epsky et al. 1994, Heath *et al*. 1994) or two weeks (Lopez-D *et al.* 1971). The situation differs if the objective is to control flies (bait sprays), as a solution of low or high optimal pH may be used in a trapping system while phytotoxicity problems may prevent its use for bait sprays. In this respect, further experiments would be needed before our results could be used for that purpose (e.g. repulsiveness or pH modification by the insecticide). The results of our study should be useful for optimizing trapping systems for both sexes of the melon fly. A possible application of these results for bait sprays with protein hydrolysate or yeast would require further field experiments.

4. CONCLUSIONS

The standard experiments conducted during the programme improved our knowledge of the effectiveness of various attractants for both sexes of the Natal fruit fly, *C. rosa*, the Peach fruit fly, *B. zonata* and the Melon fly, *B. cucurbitae*.

On the Natal fruit fly, the 2001 standard experiment, using 3C and comparing various retention systems or insecticides, showed that 3C + water + Triton was significantly more attractive than the other treatments for both sexes. The better attractiveness of this trapping system, compared with sticky insert, is probably due to a favourable effect of the presence of solution (increase of relative humidity around the trap), as both trapping systems can be considered as presenting similar odours. In the 2003 standard experiment, significantly more females were caught with NuLure than with any other treatment. No difference was observed between the two doses of AA, the 3C or Torula Yeast, which were all more attractive than Ammonium Sulphate and Di-Ammonium Phosphate (the least attractive). By contrast, in the 2005 standard experiment, the highest catches of females were obtained with Torula Yeast. Finally, in 2005, it was oberved that the 5 bait stations tested show very little attractiveness for both sexes of *C. rosa*.

On the Peach fruit fly, *B. zonata*, in the 2003 standard experiment, the highest quantity of females was caught with the higher dose of Ammonium Acetate (2AA), which attracted significantly more females than the lower dose (1/2 AA) or any other treatment. The lower dose was not significantly different from NuLure or 3C, but significantly more attractive than Torula Yeast. The poorest results were obtained with Ammonium Sulphate and Di-Ammonium Phosphate, the last one attracting very few females. In 2005, the highest catches of females were obtained with AA + TMA and the lowest with Torula. Intermediate results were obtained with 3 lures or the three treatments including 2AA.

As to the Melon fly, *B. cucurbitae*, the 2001 standard experiment showed that Torula Yeast and AA were significantly more attractive than the other attractants for both sexes. However, AA appeared more selective than Torula Yeast, which caught significantly more non-target insects than all other treatments. In the 2004 standard experiment, the highest catches of females were observed in the Multilure traps baited with 3C, while an important level of catches was also noticed with NuLure, Torula Yeast and ½ AA. Catches were generally much lower with 2 AA, Di-AP and AS.

Finally, various side experiments also allowed us to compare the relative attractiveness of a series of protein hydrolysates for both sexes of the Melon fly, and to precise the more attractive concentrations. The effects of adding borax, alkalizing or acidifying the bait mixtures was also studied in detail.

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EVALUATION OF FEMALE FRUIT FLY ATTRACTANTS IN HONDURAS 2001—2004

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Abstract

As part of an international effort coordinated by the International Atomic Energy Agency, a study to evaluate general and relative (percentage of females) efficiency of fruit fly attractants was conducted in four locations in Honduras from 2001 to 2004. Combinations of the food based dry synthetic attractants Ammonium Acetate (AA), Ammonium Bicarbonate (AB), Putrescine (PT) and Trimethylamine (TMA) were compared against NuLure® and Torula Yeast®, the standard protein lures currently used in surveillance Programmes. In the last year, pulp of hog plum, *Spondias mombin* was included in the treatments. Attractants were deployed using plastic McPhail-type traps that were checked twice weekly. The combination of AA+PT+TMA was the most efficient for the medfly, *Ceratitis capitata*, catching 0.74 flies/trap/day (FTP), whereas Torula Yeast caught 0.36 FTP. Both treatments captured over 90% females. For *Anastrepha* species, no combination of synthetic lures reached this efficiency. AA+PT and variations of it (smaller amounts of ammonia or putrescine released) gave the best results with *Anastrepha*, in some cases being statistically equal to the standard protein baits. In general, the best combination of AA+PT for each year caught an average of 0.29 FTP for *A. obliqua* and 0.23 for *A. ludens*, whereas the standard protein baits caught 0.39 and 0.42 FTP, respectively. Their relative efficiency was 77% females. Hog plum pulp gave good results in attracting *Anastrepha* flies, especially *A. obliqua*, performing equally or better than the standard protein baits. However, it only attracts around 60% females.

1. INTRODUCTION

Worldwide, fruit flies (DiPTera: Tephritidae) attack many fruit species, inducing direct losses and the implementation of quarantine restrictions that limit access to high value potential markets. Due to the success of the eradication Programme against the screwworm, *Cochliomya hominivorax*, in North and Central America [1] and the eradication of *Dacus dorsalis* from the Mariana Islands [2] using the sterile insect technique (SIT), there is an increasing interest to implement similar Programmes against economically important fruit fly species. Monitoring insect populations is essential to any pest management operation, and particularly to SIT Programmes, to determine initial population levels, population trend as a result of the Programme and detection of reinfestations after eradication [3].

Fruit flies are attracted to protein solutions, probably due to the female requirement of protein to reach sexual maturity and develop eggs [4]. Protein hydrolysates from corn, cotton, soybean and Torula Yeast have been used as baits for fruit flies [5, 6, 7, 8]. Torula Yeast has been found to be the most effective bait for fruit flies [6], and it is currently widely used in monitoring several species [8]. Attractiveness of proteins is associated with ammonia released during decomposition, acting as an olfactory attractant [9]. Effectiveness in attracting fruit flies is significantly increased when the ammonia source is used with a mixture of amino acids, which function as phagostimulants [10, 11]. A number of studies indicate that traps baited with Ammonium Acetate (AA), Putrescine (PT) and Trimethylamine (TMA) caPTure equal or greater number of female *Ceratitis capitata* than NuLure, the standard food bait [12, 13]. The study reported herein includes the evaluation of several synthetic female-targeted attractants, conducted in Honduras from 2001 to 2004, as part of a global effort sponsored by the International Atomic Energy Agency (IAEA), for the development of more effective attractants for fruit fly females that could be used in fruit fly control programmes [3].

2. MATERIALS AND METHODS

2.1. Experimental sites

Experiments were conducted in four locations in Honduras: 1) Grapefruit (*Citrus paradisi*) orchard, cv. Ruby Red, located in Municipio El Provenir, Department of Atlántida, in the Caribbean coastal plain. This orchard was established in 1989 and is currently abandoned, due to low prices in the international market. Trees were planted at 9 m between rows and 4 m within rows. This orchard was used during the four years of the study. 2) Mango (*Mangifera indica*) orchard, cv. Haden, located in Municipio La Paz, Department of La Paz, in the Comayagua Valley in central Honduras. The orchard was established in 1994. Trees were planted at 7 m by 7 m. This orchard was used only in 2001. 3) Thai guava (*Psidium guajava*) orchard at Municipio El Progreso, Department of Yoro in the Sula Valley in northern Honduras. The plantation was established in 2001. Trees were planted at 3 x 3 m. 4) Orthanique (*Citrus sinensis* x *C. reticulata*) located in Municipio Santa Cruz de Yojoa, Department of Cortés, in the area of influence of Lake Yojoa. This orchard was established in 1981. Trees were planted at 10 m between rows and 6 m within rows. Climatic conditions occurring during the development of trials are presented in Table I.

2.2. Traps and Attractants

Ammonium Acetate (AA), Ammonium Bicarbonate (AB), Putrescine (PT) and Trimethylamine (TMA) were used as synthetic food-based lures. Single and combinations of two and three lures were used in the study. AA, PT and TMA were formulated in self-sticking patches in a polyethylene membrane system (BioLure®, Suterra, 213 SW Columbia St., Bend, OR 97702-1013). AA lures are formulated to release 300 µg NH_4/hour. TMA lures were formulated loading 5 g of the hydrochloride salt into the membrane system. AB was formulated in tablets (AgriSense-BCS Limited, Pontypridd, SU, UK) releasing 150 µg NH_4/hour. Lure patches were placed in the sides of the clear top of a plastic, open-bottom, McPhail-type trap, using water with

TABLE I. CLIMATIC CONDITIONS OF THE LOCATIONS WHERE FRUIT FLY FEMALE-TARGETED ATTRACTANTS WERE EVALUATED. HONDURAS 2001 – 2004.

		La Paz	El Progreso	El Porvenir				Santa Cruz	
		2001	2002	2001	2002	2003	2004	2003	2004
Temp. ºC	Max	33.7	32.3	32.0	35.9	36.7	34.2	36.8	36.4
	Min	14.1	19.4	20.2	20.0	20.5	20.8	19.0	18.4
	Avg.	23.4	25.7	26.5	27.1	27.4	27.6	27.2	27.2
Mean rainfall (mm/yr)		792	1925	2791				2781	
Days with rain/period		11/56	23/56	25/56	35/56	19/56	24/56	18/56	20/56

TABLE II. DESCRIPTION OF THE TREATMENTS EVALUATED IN THE TRIALS OF FRUIT FLY, FEMALE-TARGETED ATTRACTANTS CONDUCTED IN HONDURAS IN 2001 – 2004.

2001	**2002**	**2003**	**2004**
NuLure	NuLure	NuLure	NuLure
AA+PT+TMA[1]	½ AA + PT	½ AA + PT	½ AA+ PT
AA+PT+TMA[2]	AA + PT	¼ AA + PT	¼ AA + PT[3]
AB+PT	2 AA + PT	½ AA	½ AA + ¼ PT
AA+ PT	2 AB + PT	2 AB	½ AB + PT
Torula Yeast	AA + PT + TMA	½ AB	¼ AA + AB + ¼ PT
	Torula Yeast		¼ AB +PT
			Hog plum pulp

AA = Ammonium Acetate, PT = Putrescine, TMA = Trimethylamine, AB = ammonium bicarbonate
2AA = 2 patches of AA, ¼ AB = ¼ tablet of AB

[1]Retention media when using synthetic attractants was water with Triton® at 2 drops per 300 ml., unless otherwise stated.
[2]Propylene glycol as retention media
[3]Sticky card as retention media

Triton® (2 drops/300 ml) as retention media for captured insects. Lures were replaced after four weeks in the field. When smaller amounts of volatiles were required, the opening of the patch was partially closed with aluminum tape, i. e., in a treatment with ½AA, half of the opening was taped; in ¼PT, only ¼ of the opening of the Putrescine patch was exposed; the treatment 2AA had two Ammonium Acetate patches (Table II). In 2001 and 2002, the protein attractants Torula Yeast and NuLure® (Miller Chemical and Fertilizer, Hanover, PA) were used as controls. In 2003 and 2004 only NuLure® was used as control. The Torula Yeast bait was prepared using three pellets (15 g) of Torula Yeast with 3% borax mixed with 300 ml of water. The NuLure bait was used as an aqueous solution with 9% NuLure and 3% borax. The bait of these two treatments was replaced every week. All traps were checked twice weekly for captured flies. The water used for retention in the other treatments was also replaced every week. When necessary, water was added to the traps during the mid week revision. In 2004, pulp of hog plum, *Spondias mombin*, the most preferred host of *Anastrepha obliqua*, diluted at 50% in water, was included in the experiments. This material was also renewed every week. This pulp was obtained from trees used as live fences. Green fruits were protected in the trees with paper bags to prevent fruit fly infestation. Upon ripening they were collected and the pulp was extracted and kept frozen until needed. Treatments for each year are presented in Table II. In all trials, the experimental unit was a single trap and lasted eight weeks.

2.3. Field tests

2001. Six treatments (Table II) were evaluated in a 6 x 6 Latin square. The first experiment was established at the mango orchard at La Paz, starting on April 17. The second trial was established at the grapefruit orchard at El Porvenir, Atlántida on August 14.

2002. Seven treatments (Table II) were evaluated using a randomized complete block design with five replications. Treatments were re-randomized every week. The first experiment was established at the grapefruit orchard at El Porvenir, Atlantida on August 22. The second experiment was conducted at the guava orchard at El Progreso, Yoro, starting on November 28.

Experiments in 2003 were conducted at the grapefruit orchard at El Porvenir Atlántida and the orthanique orchard at Santa Cruz de Yojoa, starting on August 28 and 29, respectively. Six treatments (Table II) were evaluated using a randomized complete block design with five replications. Treatments were re-randomized every week.

2004. Experiments were conducted at the same sites of 2003, starting on August 19 and 20, respectively. Eight treatments (Table II) were evaluated using a randomized complete block design with five replications and weekly re-randomization of treatments.

2.4. Data collection and analysis

Data on captured fruit flies were collected every time traps were visited, recording number of males and females and non-target species captured. Data was analyzed using the GLM function of SYSTAT®. When significant differences among treatments were detected, means were separated using Fisher's LSD. Prior to the analysis of variance caPTure data was transformed to $\log_{10}(x+1)$ and percentage data to $\sqrt{x + 0.5}$.

3. RESULTS AND DISCUSSION

3.1. Year 2001

Mango orchard. Similar number of *Ceratitis capitata* and *Anastrepha obliqua* were captured (51.2 and 48.5% of total catch, respectively). The analysis of variance detected significant differences in total efficiency of the attractants to capture *C. capitata* and *A. obliqua*. No significant differences in the percent female captures for both species was detected. All treatments captured higher than 90% females of *C. capitata*, excePT for AB + PT (Table III). The proportion of *A. obliqua* females was lower than that of *C. capitata* for every treatment, ranging from 48.56 to 82.52% (Table III). Both treatments containing AA + PT + TMA were the most efficient to caPTure *C. capitata*, with an average of 0.71 and 0.74 flies per trap per day (FTP), respectively (Table III). Both treatments with the three components were also more efficient than the other treatments to capture medflies at the beginning of the experiments, when the population was low. They were also very efficient in capturing females, especially when the population was low (FIG. 1). For the capture of *A. obliqua*, the best treatments were Torula Yeast and AA + PT, with 1.05 and 0.86 FTP, respectively (Table III). Both treatments were able to capture *A. obliqua* when the population was low. It is significant that at the beginning of the experiment (low population) all captures in Torula were females and as the population increased the proportion of females declined (FIG. 2). The average capture of other insects was relatively low with the exception of NuLure®, which captured an average of 39.59 insects per day. In general, most of non-target insects were muscid flies (Diptera: Muscidae) and very few beneficial insects. Among the beneficial insects, lacewings (NeuróPTera: Chrysopidae) were the most frequently observed.

TABLE III. AVERAGES OF CAPTURED FLIES, PERCENT FEMALES AND OTHER INSECTS CAPTURED IN THE FRUIT FLY ATTRACTANTS EXPERIMENT CONDUCTED AT THE MANGO ORCHARD AT LA PAZ. APRIL-JUNE, 2001.

	Ceratitis capitata		***Anastrepha obliqua***		**Other**
Treatment	**FTD[1]**	**% females**	**FTD**	**% females**	**Insects[3]**
NuLure	0.09 d[2]	93.75	0.21 b	61.70	39.59 a
AA+PT+TMA W	0.71 a	93.37	0.20 b	82.52	8.74 b
AA+PT+TMA PG	0.74 a	94.66	0.24 b	72.16	7.90 b
AB+PT	0.30 c	65.87	0.32 b	63.65	6.00 b
AA+ PT	0.56 ab	92.95	0.86 a	48.56	7.90 b
Torula Yeast	0.36 bc	94.59	1.05 a	75.59	9.07 b

[1]Flies/trap/day
[2]Means followed by the same letter are not significantly different (LSD, p=0.05)
[3]Insects/trap/day.

Grapefruit orchard. In this location, *A. ludens* was the dominant species, with 92.4% of the total fruit flies captured. The remaining 7.6% was *A. obliqua*. The analysis of variance detected significant differences in the efficiency to attract *A. ludens* and *A. obliqua*. Torula Yeast attracted significantly more individuals of both species than the remaining attractants (*A. ludens* 0.69 FTP and *A. obliqua* 0.07 FTP) (Table IV). The analysis of variance did not detect significant differences in percent females captures for *A ludens*. Treatment AB+PT captured 100% females, but had the lowest FTP value (0.01 FTP). The analysis did not detect significant differences in the percent females of *A. obliqua* captured (Table IV). The results of weekly observations are presented in figures 3 and 4 for *A. ludens* and *A. obliqua*, respectively. Torula Yeast consistently captured *A. ludens* throughout the experiment. The proportion of females varied between 50 and 100%. A tendency to caPTure a higher proportion of females when population is low was observed (FIG. 3). Captures of *A. obliqua* were low during the period (FIG. 4). As in La Paz, treatment NuLure captured significantly more non-target insects than the remaining treatments, with a mean of 24.38 insects per trap per week (Table IV).

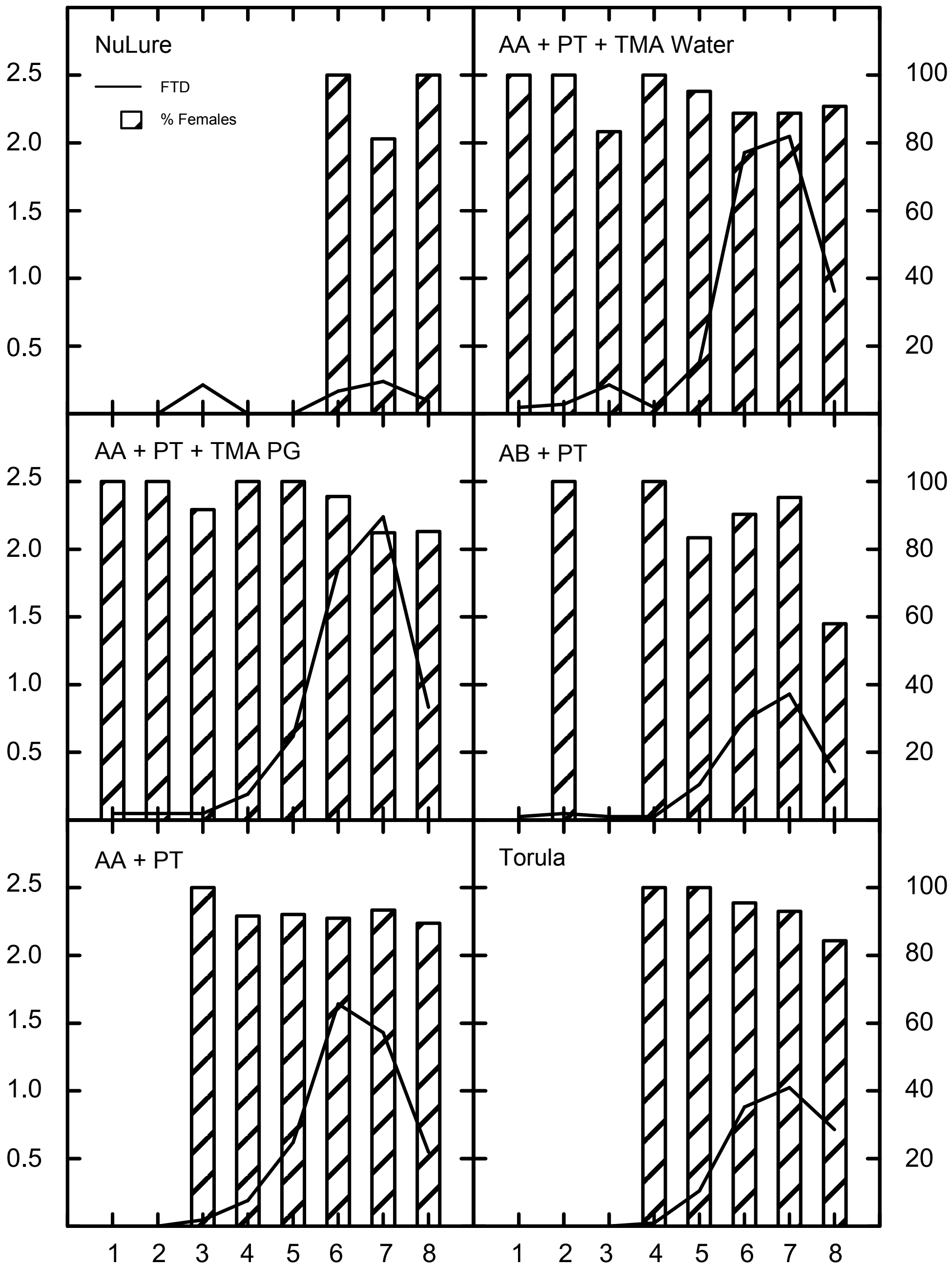

FIG. 1. Weekly captures of the Mediterranean fruit fly Ceratitis capitata*, in the treatments evaluated in the female-targeted attractants evaluation conducted in a mango orchard at Municipio La Paz, Department of La Paz, Honduras. April – June 2001.*

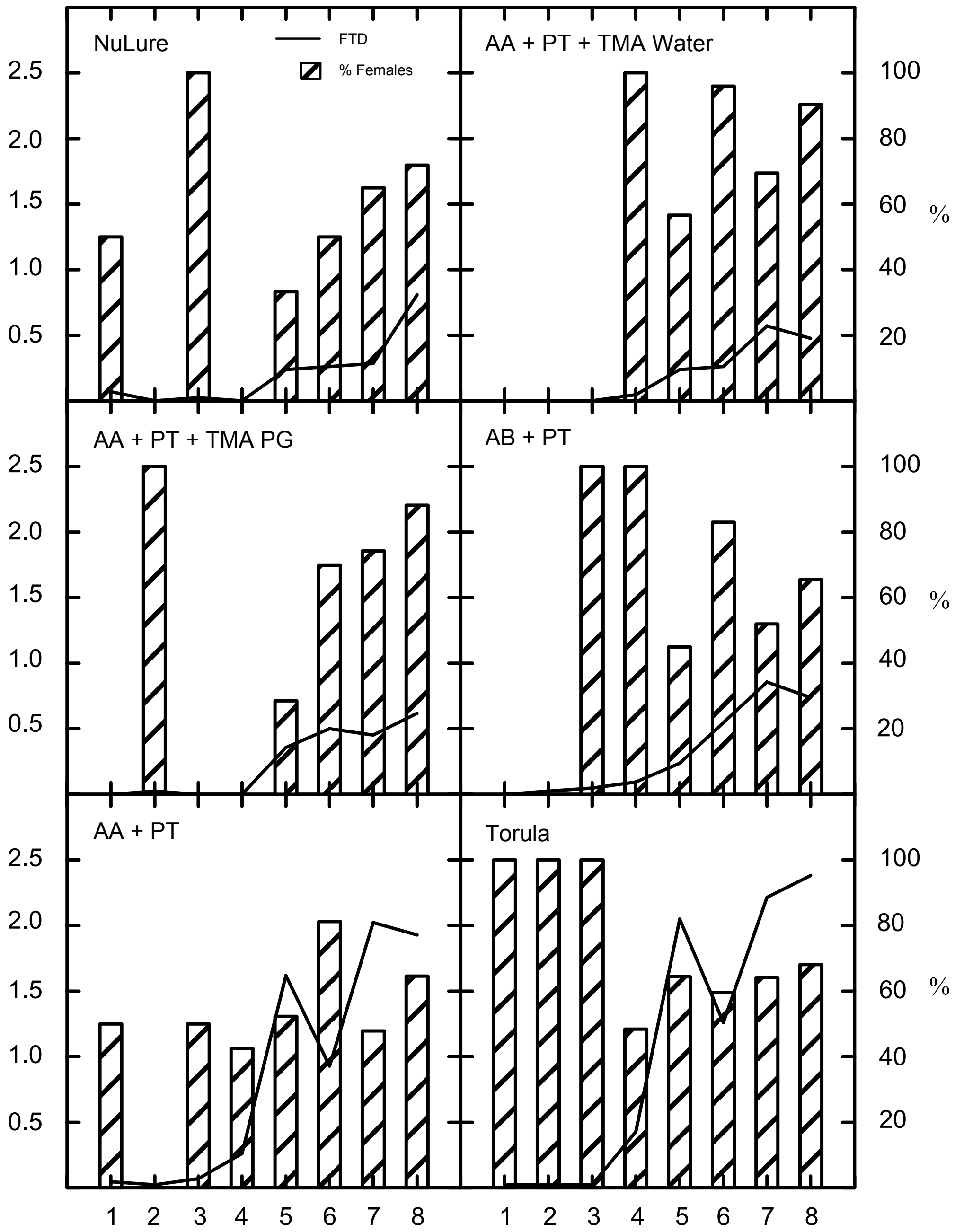

FIG. 2. Weekly captures of the Mango fruit fly Anastrepha obliqua*, in the treatments evaluated in the female-targeted attractants evaluation conducted in a mango orchard at Municipio La Paz, Department of La Paz, Honduras. April – June 2001.*

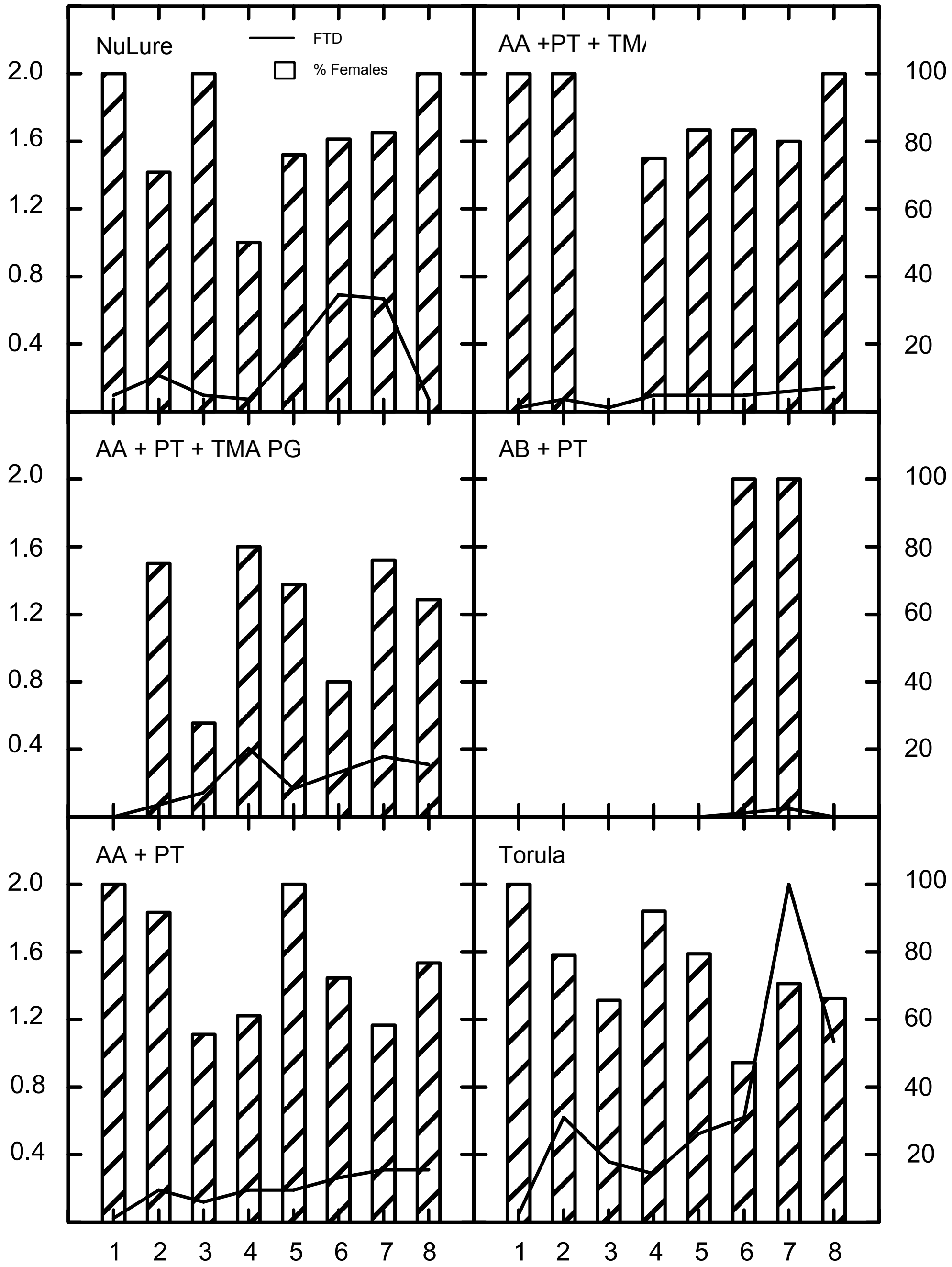

FIG. 3. Weekly captures of the Mexican fruit fly Anastrepha ludens*, in the treatments evaluated in the female-targeted attractants evaluation conducted in a grapefruit orchard at Municipio El Porvenir, Department of Atlántida, Honduras. August – October 2001.*

3.2. Year 2002

Grapefruit orchard. As in the previous year, *A. ludens* was the dominant species, with 83.9% of the total caPTure, followed by *A. obliqua* with 15.5% and *C. capitata* with 0.6%. The analysis of variance detected significant differences in captures of both species of A*nastrepha*. Torula Yeast attracted significantly more *A. ludens* (0.95 FTD) and was statistically similar to NuLure to attract *A. obliqua* (Table V). With the excePTion of 2 AB+PT, the treatments were not different in the proportion of *A ludens* females captured. For *A. obliqua*, AA+PT had the highest proportion of females, which was not significantly different from NuLure (Table V). Both species of *Anastrepha* seem to respond better to combinations of AA+ PT than to the other combinations of synthetic lures. Lower captures of *A. obliqua* are likely to be related to the size of the population. The results of weekly observations are presented in figures 5 and 6. A similar trend of captures of *A. ludens* is observed for Torula, NuLure and ½AA+PT (FIG 5). Captures of non-target insects (mostly muscid flies) was lower than 15 insects per trap per week for any treatment throughout the experiment.

TABLE IV. AVERAGES OF CAPTURED FLIES, PERCENT FEMALES AND OTHER INSECTS CAPTURED IN THE FRUIT FLY ATTRACTANTS EXPERIMENT CONDUCTED AT THE GRAPEFRUIT ORCHARD AT EL PORVENIR, ATLÁNTIDA, AUGUST-OCTOBER, 2001.

	Anastrepha ludens		***Anastrepha obliqua***		**Other**
Treatment	**FTD[1]**	**% females**	**FTD**	**% females**	**Insects[3]**
NuLure	0.28 b[2]	82.51	0.02 b	43.75	24.38 a
AA+PT+TMA W	0.08 cd	77.71	0.01 b	50.00	9.05 c
AA+PT+TMA PG	0.21 bc	61.69	0.01 b	50.00	13.57 b
AB+PT	0.01 d	100.00	0.00 b	.	3.48 d
AA+ PT	0.20 bc	76.94	0.02 b	75.00	8.45 c
Torula Yeast	0.69 a	75.04	0.07 a	42.29	16.69 b

[1]Flies/trap/day
[2]Means followed by the same letter are not significantly different (LSD, p=0.05)
[3]Insects/trap/day

Guava orchard. A total of 12 fruit fly specimens were captured during the 8 weeks of the experiment, 9 of *A. striata* (8 females) and 3 of *A. obliqua* (all females). The low catches may be related to the management of the fruits, which are individually wrapped with a plastic bag to prevent infestation. Besides, during the eight weeks the experiment lasted, weather conditions were unfavorable for fruit flies (low temperatures with frequent drizzle and overcast), which could further affect the population. Fruit collections did not yield larvae or pupae. Considering the low catches, no statistical analysis was performed.

3.3. Year 2003

Grapefruit orchard. In this experiment *Anastrepha ludens* was the dominant species with 72% of the total catch. The remaining 28% were *A. obliqua*. Overall, NuLure captured significantly more *A. ludens* and *A. obliqua* than any other treatment (Table VI). As observed in the previous year, among the synthetic lures, the combinations of AA+PT tended to catch more individuals of both species. In spite of large variations, the analysis did not detect differences in the percentage of females of *A. ludens* and *A. obliqua* captured in the treatments of the experiment (Table VI). The results of weekly observations are presented in FIGS. 7 and 8. For both species, NuLure was the most consistent to caPTure both species throughout the experiment, capturing higher than 60% females most of the weeks (FIGS. 7 and 8).

TABLE V. AVERAGES OF CAPTURED FLIES AND PERCENT FEMALES IN THE FRUIT FLY ATTRACTANTS EXPERIMENT CONDUCTED AT THE GRAPEFRUIT ORCHARD AT EL PORVENIR, ATLÁNTIDA, AGOSTO-OCTUBRE, 2002.

	Anastrepha ludens		*Anastrepha obliqua*	
Treatment	FTD[1]	% females	FTD	% females
NuLure	0.61 b[2]	88.40 a	0.18 a	74.51 ab
½ AA + PT	0.46 bc	87.99 a	0.06 b	63.54 ab
AA + PT	0.32 bcd	84.88 a	0.06 b	90.22 a
2 AA + PT	0.23 cde	74.72 a	0.03 b	70.00 ab
2 AB + PT	0.09 e	31.07 b	0.01 b	50.00 b
AA + PT + TMA	0.21 de	78.02 a	0.01 b	0.00
Torula Yeast	0.95 a	79.59 a	0.25 a	62.90 b

[1]Flies/trap/day
[2]Means followed by the same letter are not significantly different (LSD, p=0.05)

Orthanique orchard. Total capture of *Anastrepha obliqua* (55.1%) was higher than that of *A. ludens* (40.8%). Small numbers of *Ceratitis capitata* (3.4%) and *A. striata* (0.6%) were also captured. For *A. ludens*, treatments ½AA+PT, ¼AA+PT and NuLure had the highest captures (Table VII). For *A. obliqua*, a similar situation to that of *A ludens* was observed (Table VII). The analysis of variance did not detect differences in the capture of females of both species. Captures of *A. ludens* with ½AA+PT were consistent throughout the experiment, with 60% or more females most of the weeks (FIG. 9). NuLure and ¼AA+PT were similar to ½AA+PT, but there was more variation in the proportion of females captured. Among the synthetic lures, ½AA+PT tends to be the most consistent in attracting *A. obliqua* with 60% females or more most of the weeks of the experiments (FIG. 10).

3.4. Year 2004

Grapefruit orchard. As in the previous years, *A. ludens* was the dominant species, with 66% of the total catch, followed by *A. obliqua* with 32%. One *A. striata* and 5 *C. capitata* were also captured. Overall, NuLure and hog plum pulp had the highest catches of *A. ludens*, a tendency observed throughout the experiment (FIG. 11). Of the synthetic lures, ½AA+¼PT had the highest catches, statistically similar to hog plum pulp; it consistently caught flies every week of the experiment with 60% or more females (Table VIII). For *A. obliqua*, hog plum pulp captured significantly more flies than any other treatment (Table VIII), a tendency observed consistently every week of the experiment (FIG. 12). However, it tends to attract similar number of both sexes (overall 54.62% females of *A ludens* and 53.08% of *A. obliqua*) (Table VIII). The analysis of variance did not detect significant differences in the proportion of captured females for both species (Table VIII), in spite of more than 40% difference between lowest and highest values for both species. This is probably related to the high variability observed in the data.

Table VI. Averages of captured flies and percent females in the fruit fly attractants experiment conducted at the grapefruit orchard at El Porvenir, Atlántida, Agosto-Octubre, 2003.

	Anastrepha ludens		***Anastrepha obliqua***	
Treatment	**FTD[1]**	**% females**	**FTD**	**% females**
NuLure	0.18 a[2]	77.40	0.11 a	79.76
½ AA + PT	0.07 b	62.50	0.04 b	58.33
¼ AA + PT	0.09 b	63.57	0.05 b	72.00
½ AA	0.07 b	80.56	0.01 b	100.00
2 AB	0.07 b	78.57	0.01 b	66.67
½ AB	0.04 b	31.94	0.02 b	33.33

[1]Flies/trap/day
[2]Means followed by the same letter are not significantly different (LSD, p=0.05)

Table VII. Averages of captured flies and percent females captured in the fruit fly attractants experiment conducted at the othanique orchard at Santa Cruz de Yojoa, Cortés, Agosto-Octubre, 2003.

	Anastrepha ludens		***Anastrepha obliqua***	
Treatment	**FTD[1]**	**% females**	**FTD**	**% females**
NuLure	0.09 ab[2]	82.78	0.19 a	74.60
½ AA + PT	0.12 a	75.69	0.14 ab	65.14
¼ AA + PT	0.09 ab	71.43	0.11 b	68.65
½ AA	0.04 bc	70.83	0.01 c	33.33
2 AB	0.01 c	50.00	0.00 c	.
½ AB	0.08 ab	37.59	0.10 b	81.58

[1]Flies/trap/day
[2]Means followed by the same letter are not significantly different (LSD, p=0.05)

Orthanique orchard. In general, captures of flies were about 40% lower than in the previous year, probably affected by lower than normal rainfall in May through July. Similar number of specimens of *A. obliqua* (50.6%) and *A. ludens* (46.5%) were captured. Hog plum pulp and NuLure had the highest captures of *A. ludens* (Table 9). Of the synthetic lures, ½AA+¼PT had the highest FTP value, which was statistically equal to NuLure (Table 9). For *A. obliqua*, hog plum pulp captured significantly more flies than the remaining treatments, followed by NuLure (Table IX). The FTP values of ½AA+PT and ½AA+¼PT were not different from NuLure (Table IX). No statistical difference in percentage of captured females was observed for both species. Captures of both species were low during the eight weeks of the experiment (FIGS. 13 and 14). Hog plum pulp captured flies of both species of *Anastrepha* every week of the experiment, but the proportion of females of *A. ludens* was rather erratic (FIG. 13). For *A. obliqua*, the proportion of females was more stable, with 60% or higher in six weeks (FIG. 14).

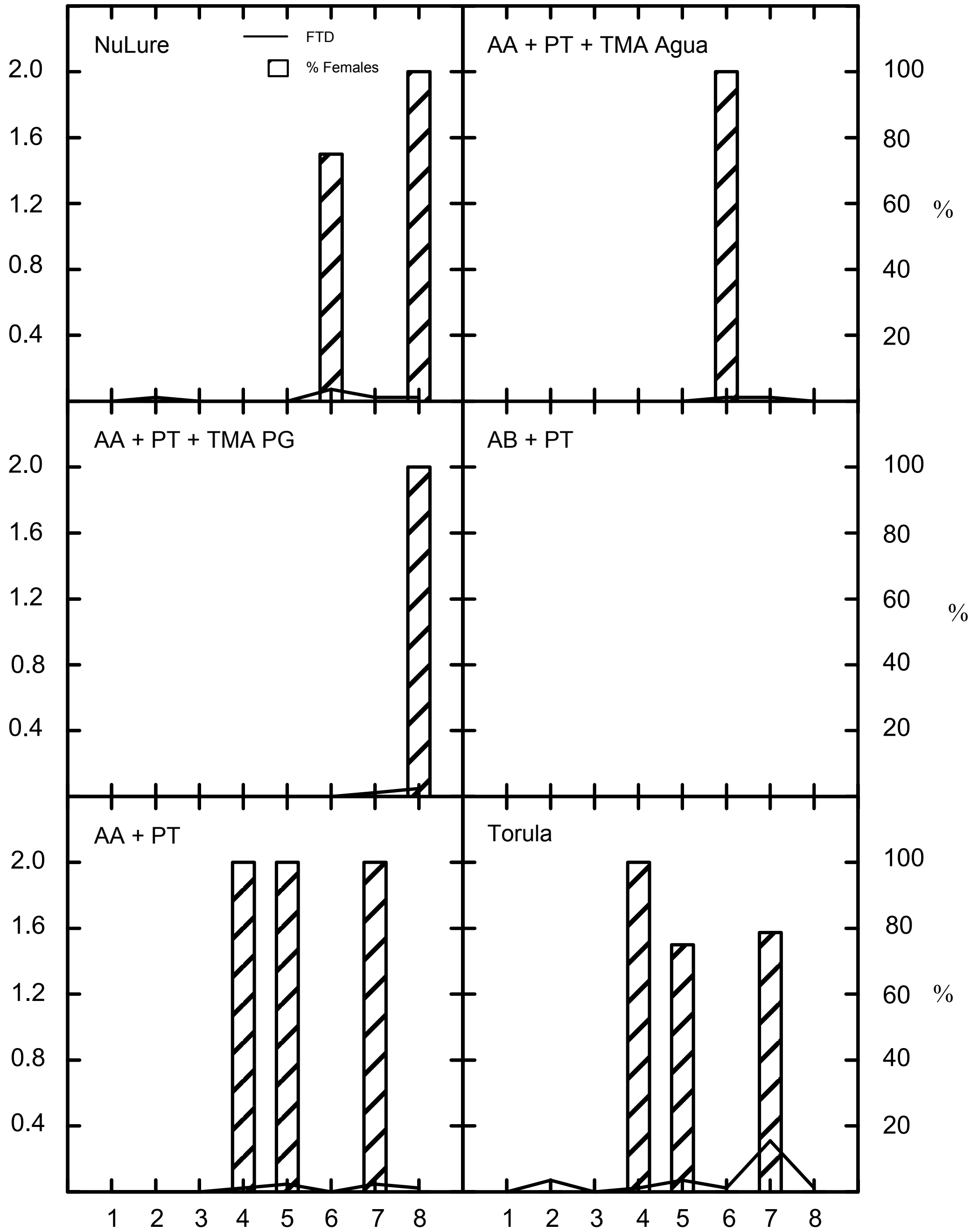

FIG. 4. Weekly captures of the Mango fruit fly Anastrepha obliqua*, in the treatments evaluated in the female-targeted attractants evaluation conducted in a grapefruit orchard at Municipio El Porvenir, Department of Atlántida, Honduras. August – October 2001.*

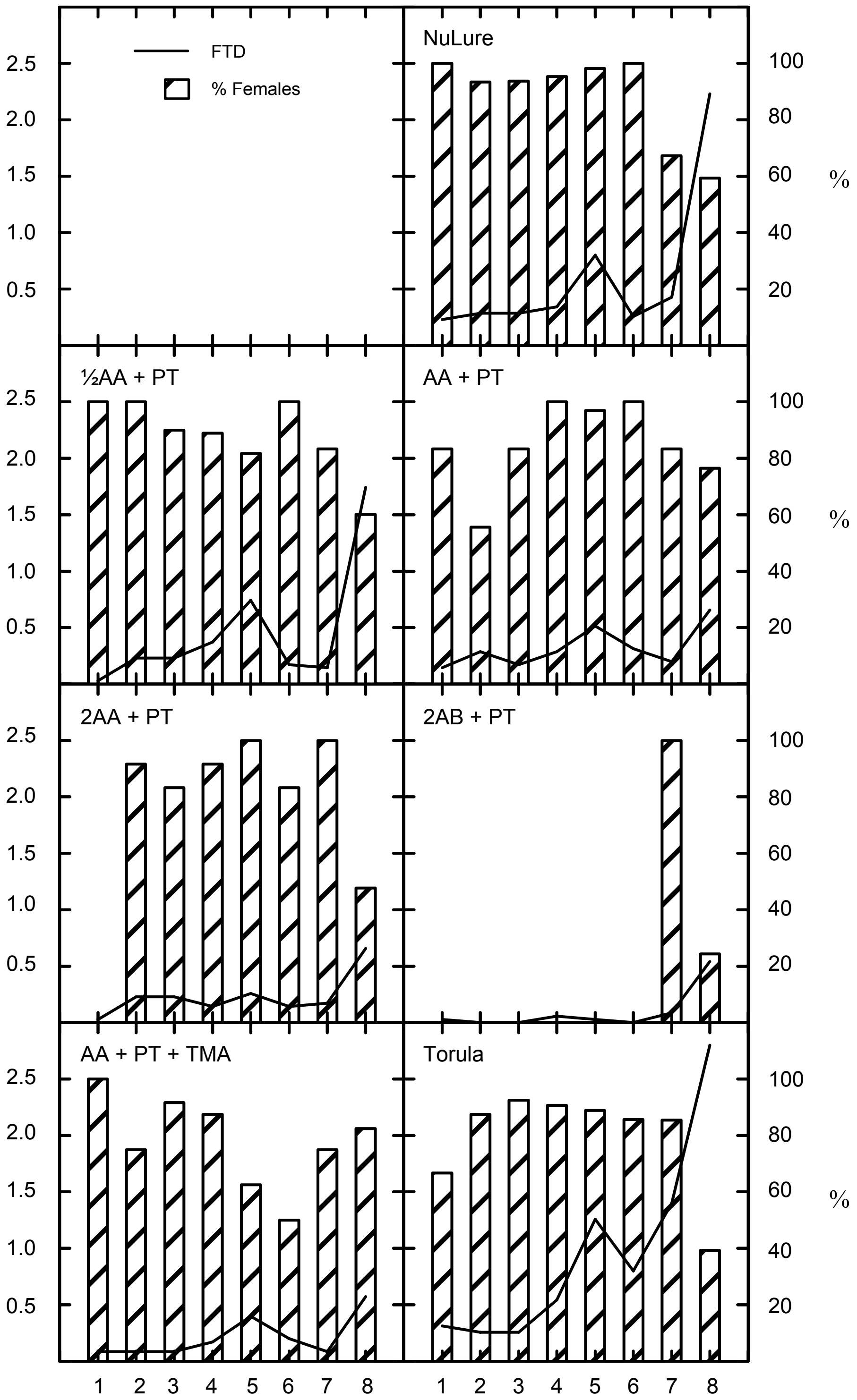

FIG. 5. Weekly captures of the Mexican fruit fly Anastrepha ludens*, in the treatments evaluated in the female-targeted attractants evaluation conducted in a grapefruit orchard at Municipio El Porvenir, Department of Atlántida, Honduras. August – October 2002.*

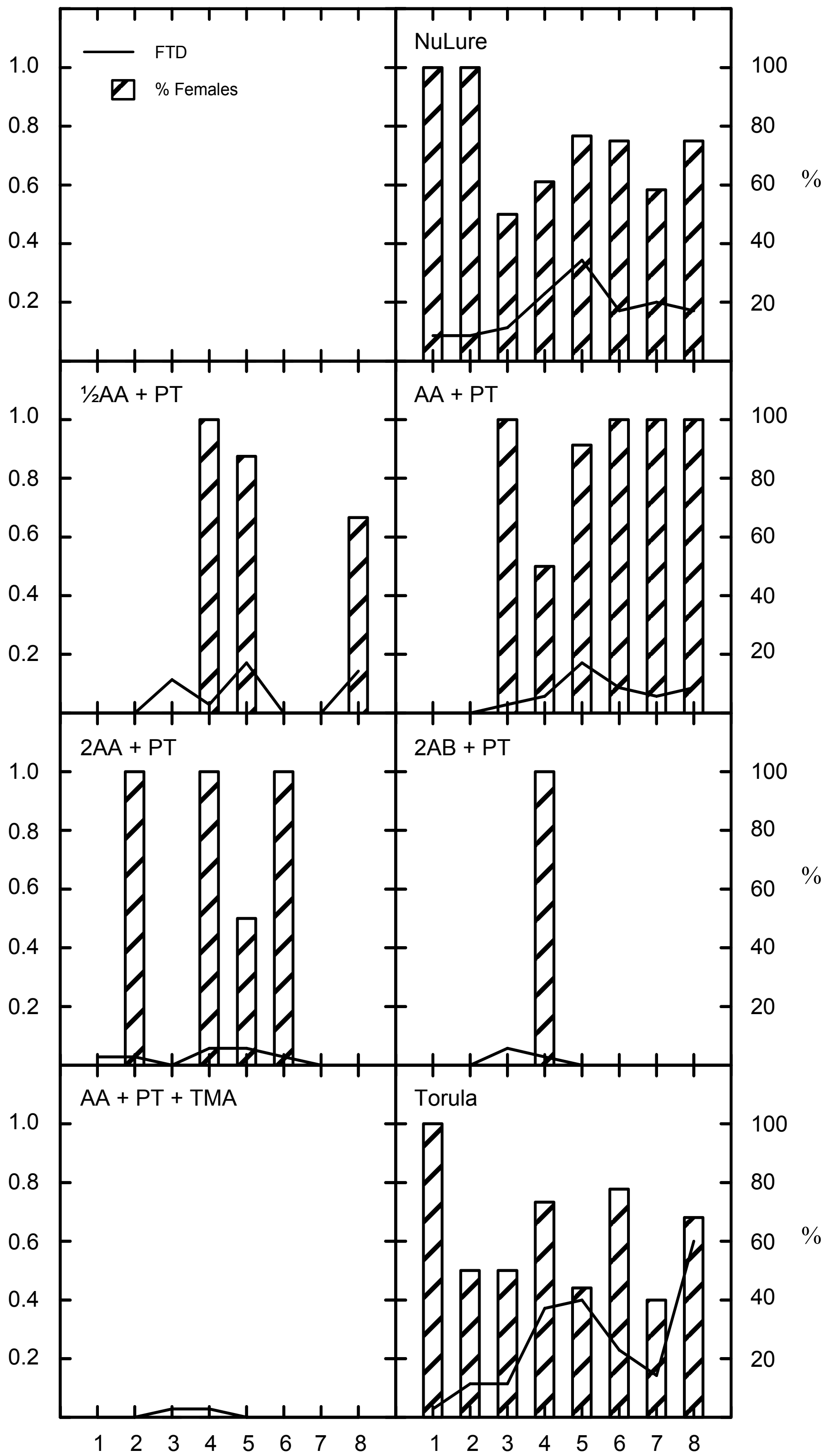

FIG. 6. Weekly Captures of the Mango fruit fly Anastrepha obliqua*, in the treatments evaluated in the female-targeted attractants evaluation conducted in a grapefruit orchard at Municipio El Porvenir, Department of Atlántida, Honduras. August – October 2002.*

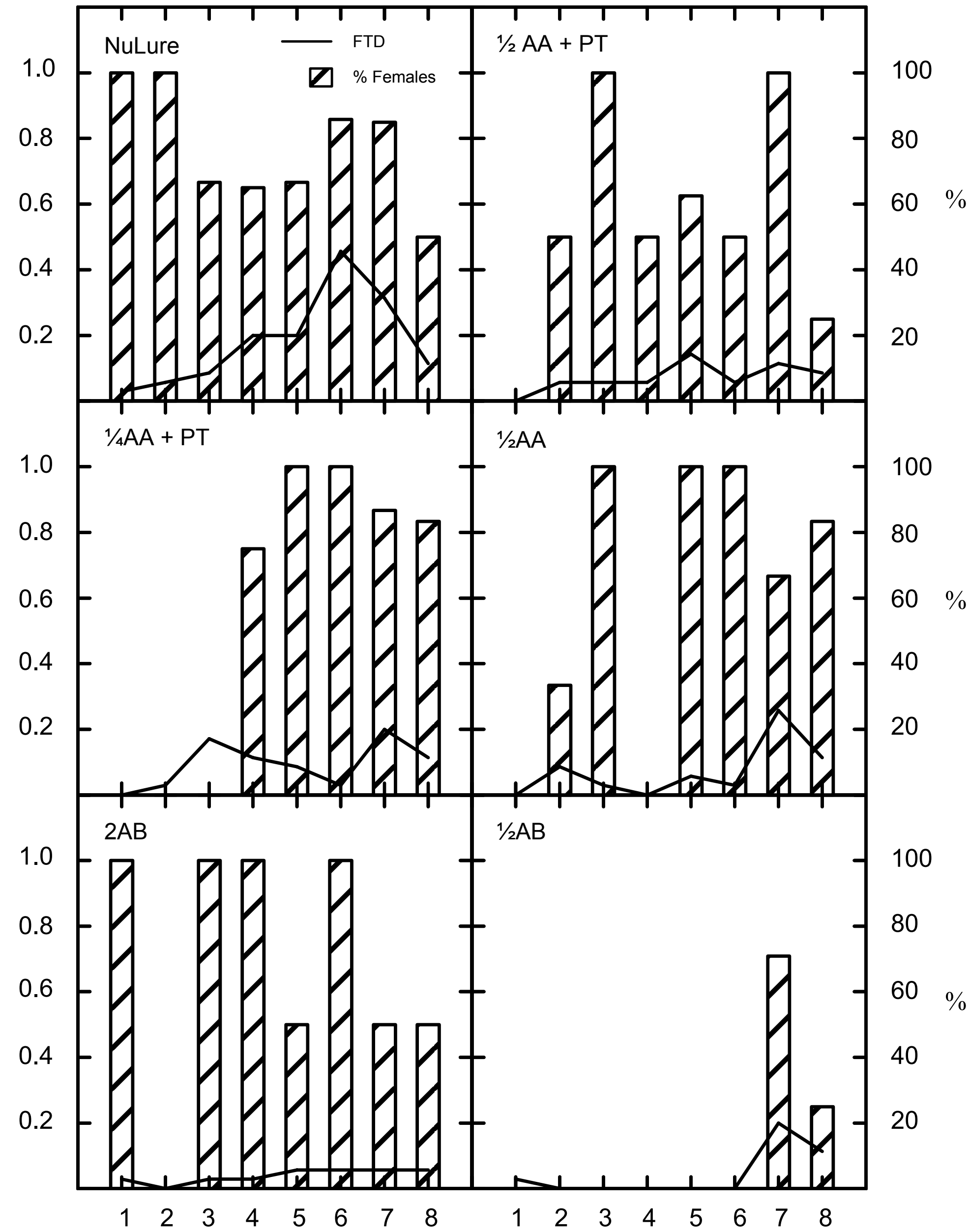

FIG. 7. Weekly captures of the Mexican fruit fly Anastrepha ludens*, in the treatments evaluated in the female-targeted attractants evaluation conducted in a grapefruit orchard at Municipio El Porvenir, Department of Atlántida, Honduras. August – October 2003.*

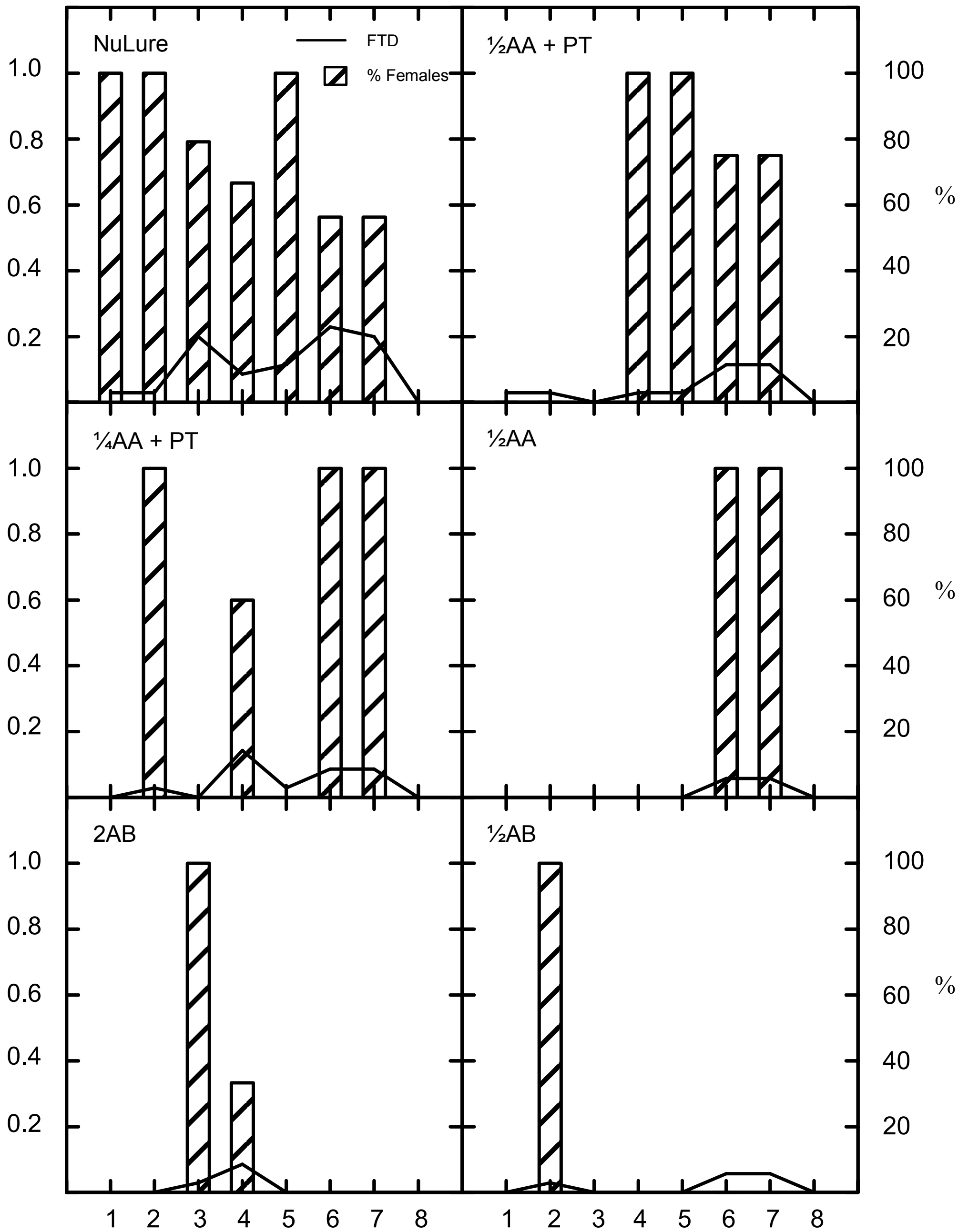

FIG. 8. Weekly captures of the Mango fruit fly Anastrepha obliqua*, in the treatments evaluated in the female-targeted attractants evaluation conducted in a grapefruit orchard at Municipio El Porvenir, Department of Atlántida, Honduras. August – October 2003.*

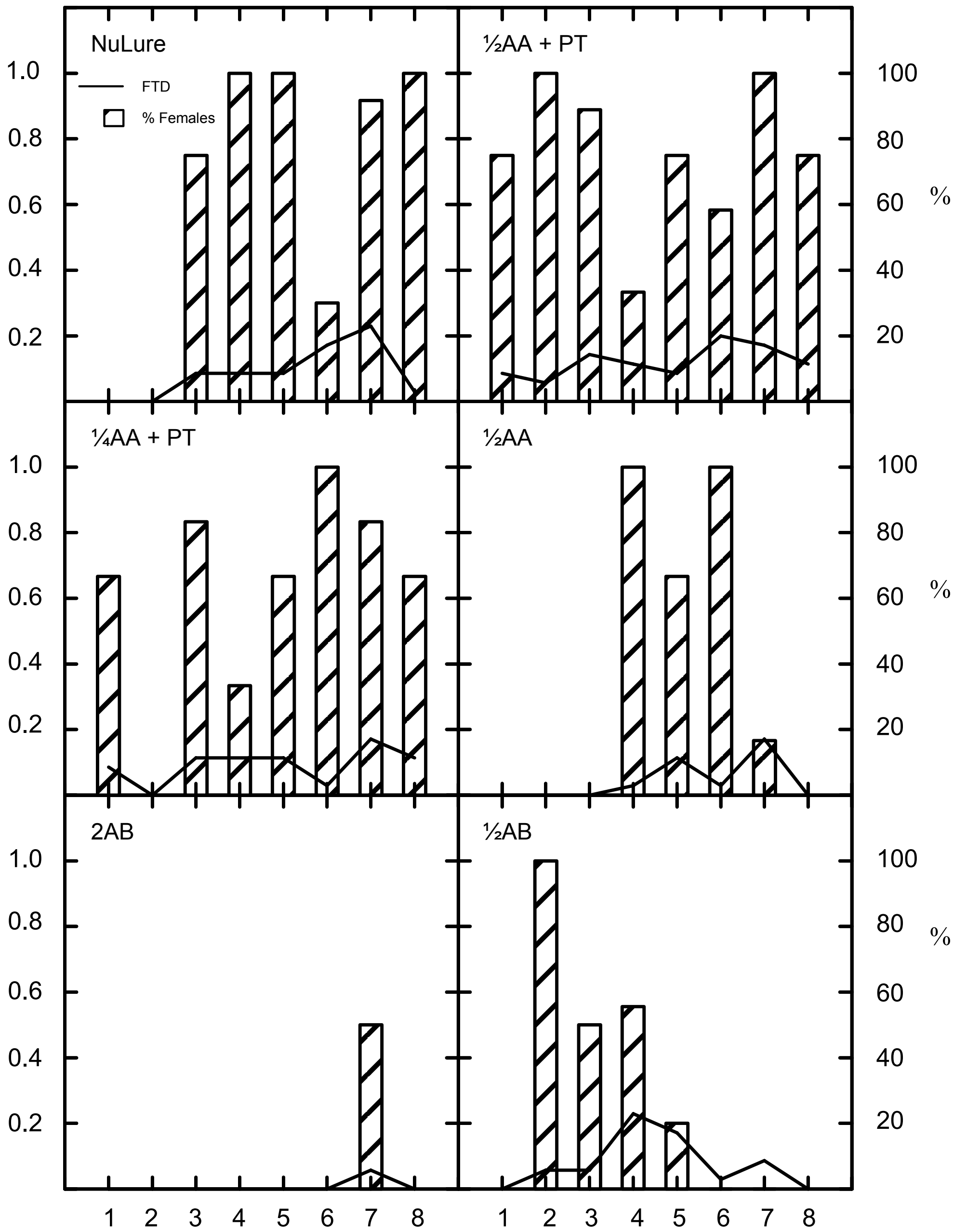

FIG. 9. Weekly captures of the Mexican fruit fly Anastrepha ludens*, in the treatments evaluated in the female-targeted attractants evaluation conducted in an orthanique orchard at Municipio Santa Cruz de Yojoa, Department of Cortés, Honduras. August – October 2003.*

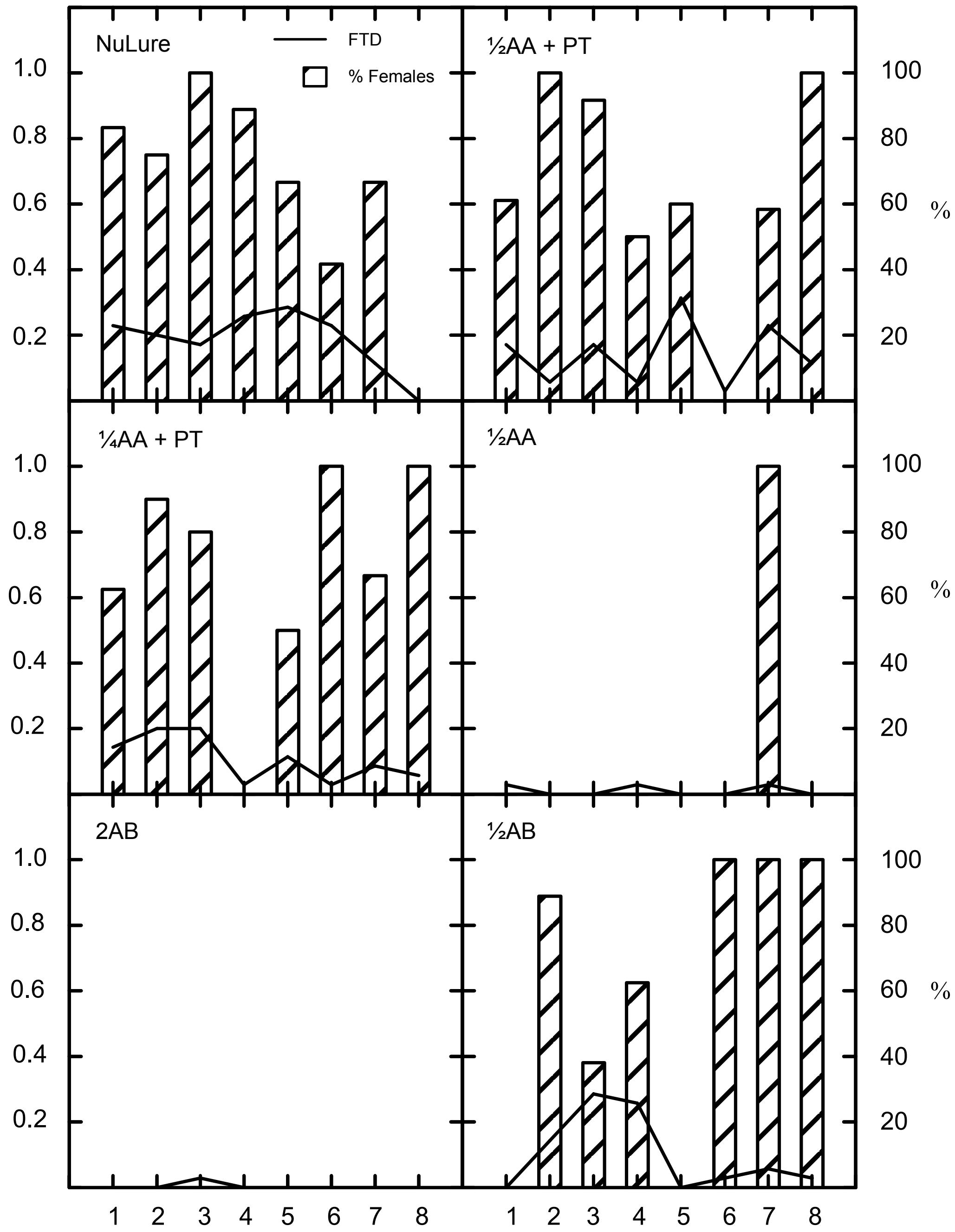

FIG. 10. Weekly captures of the Mango fruit fly Anastrepha obliqua*, in the treatments evaluated in the female-targeted attractants evaluation conducted in an orthanique orchard at Municipio Santa Cruz de Yojoa, Department of Cortés, Honduras. August – October 2003.*

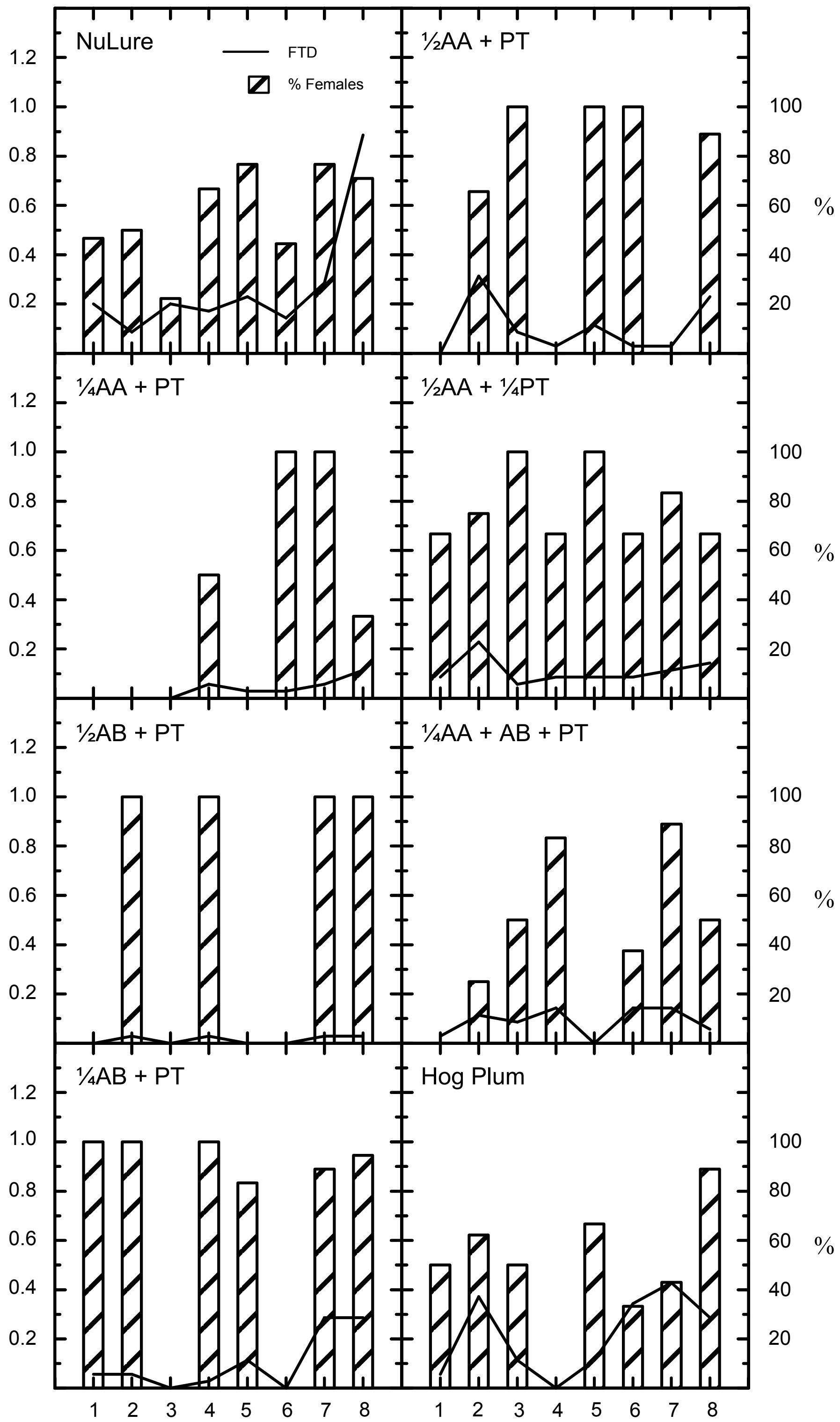

FIG. 11. Weekly captures of the Mexican fruit fly Anastrepha ludens*, in the treatments evaluated in the female-targeted attractants evaluation conducted in a grapefruit orchard at Municipio el Porvenir, Department of Atlántida, Honduras. August – October* 2004.

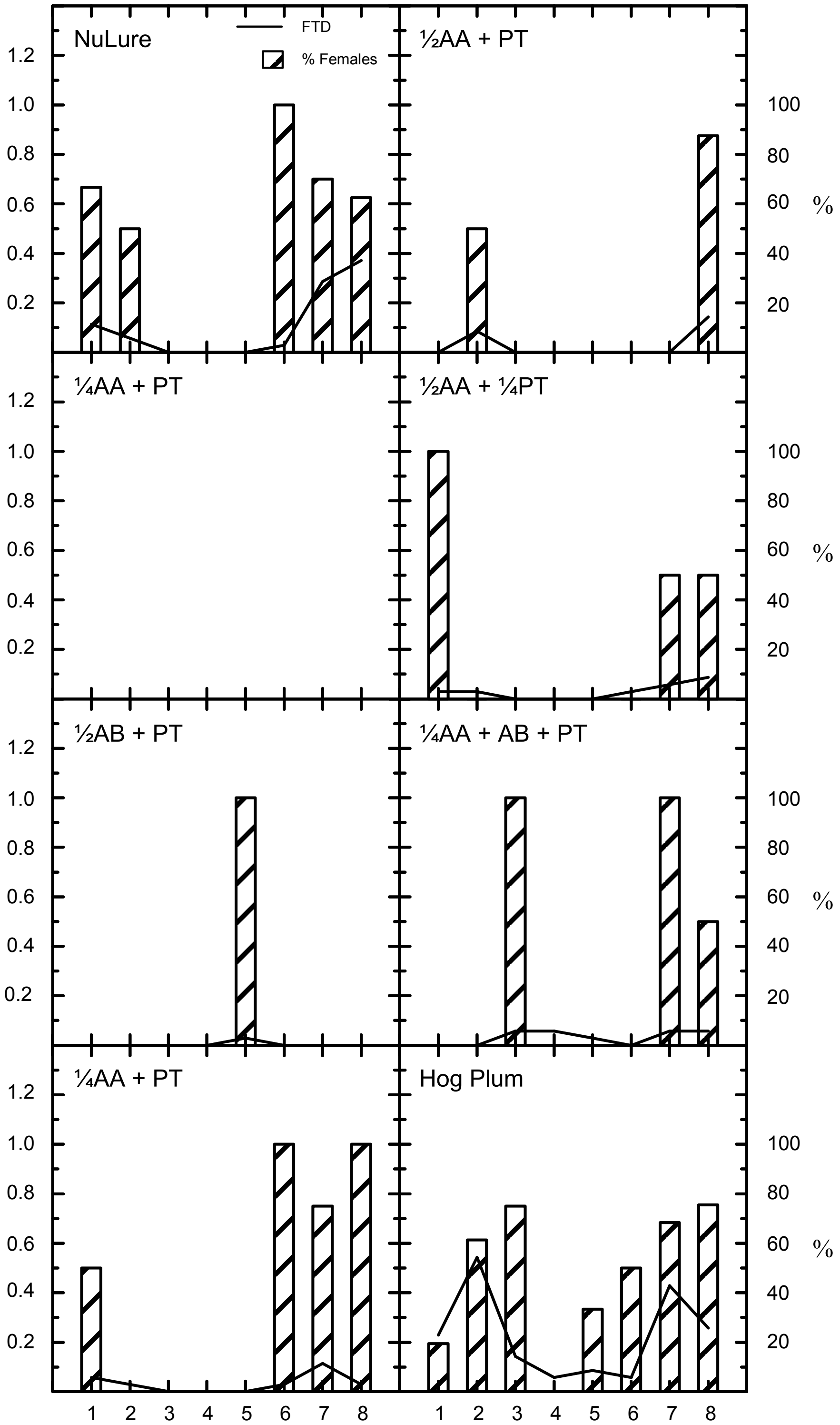

FIG. 12. Weekly captures of the Mango fruit fly Anastrepha obliqua*, in the treatments evaluated in the female-targeted attractants evaluation conducted in an orthanique orchard at Municipio El Porvenir, Department of Atlántida, Honduras. August – October 2004.*

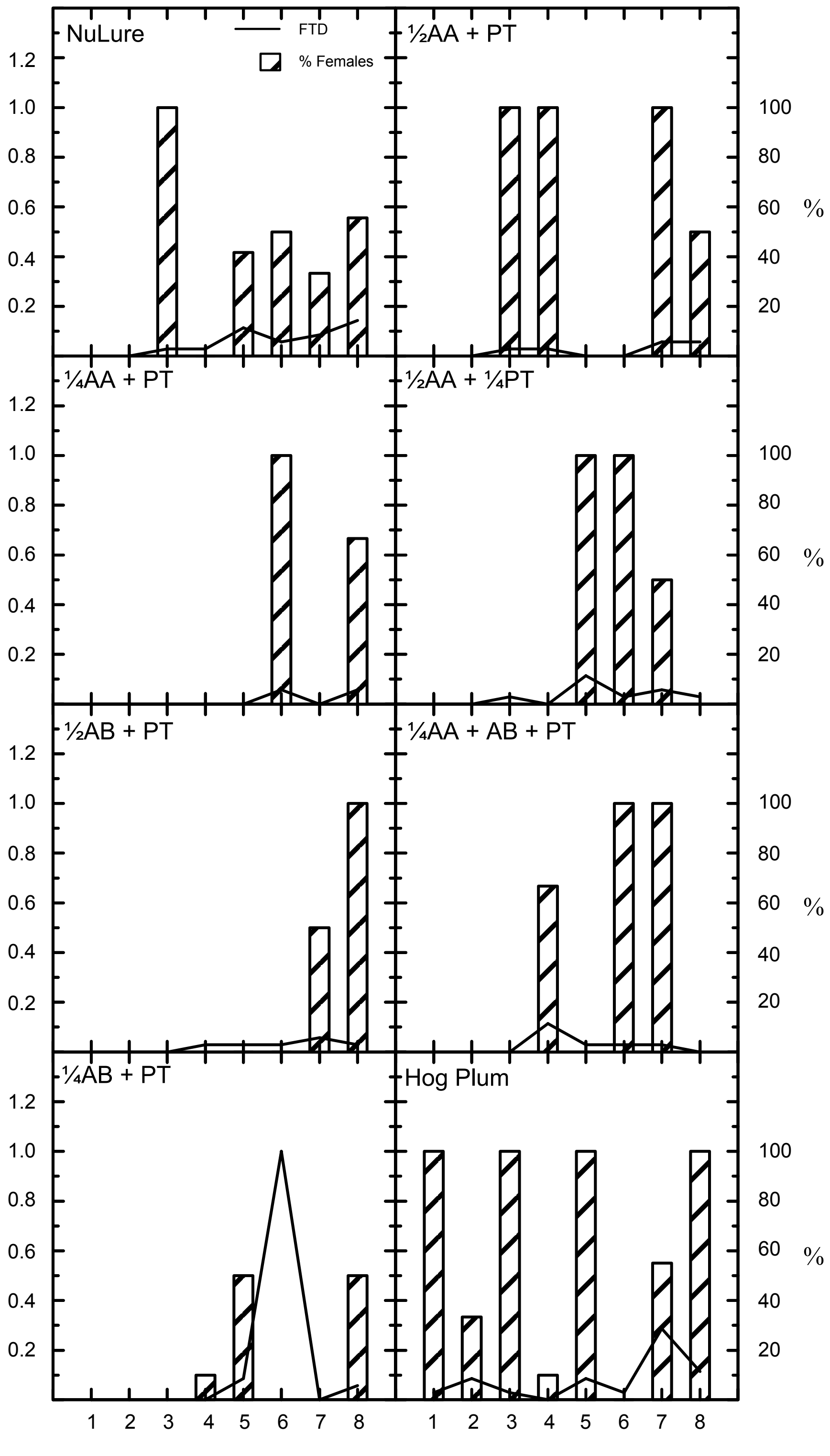

FIG. 13. Weekly captures of the Mexican fruit fly Anastrepha ludens*, in the treatments evaluated in the female-targeted attractants evaluation conducted in an orthanique orchard at Municipio Santa Cruz de Yojoa, Department of Cortés, Honduras, August – October 2004.*

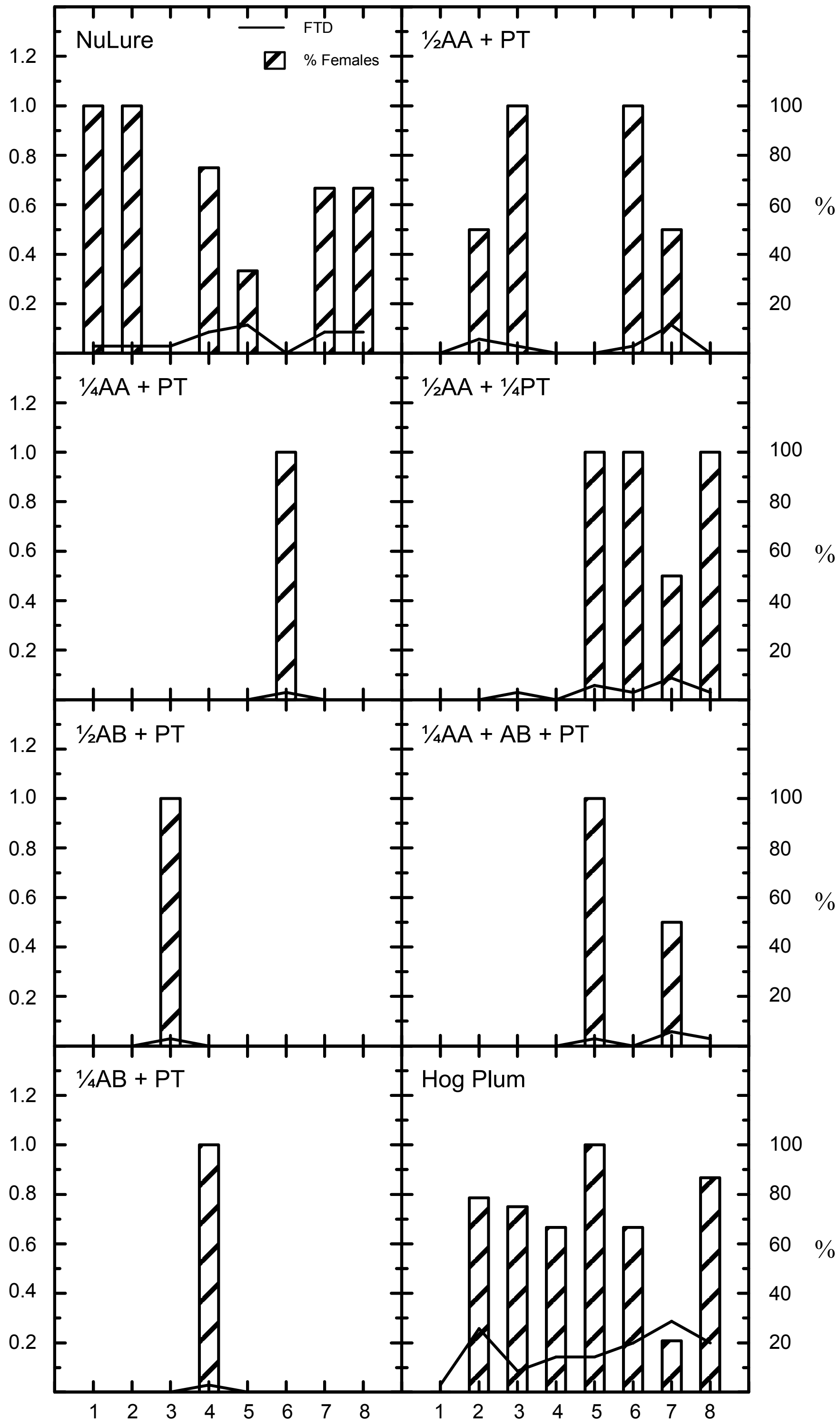

FIG. 14. Weekly captures of the Mango fruit fly Anastrepha obliqua*, in the treatments evaluated in the female-targeted attractants evaluation conducted in an orthanique orchard at Municipio Santa Cruz de Yojoa, Department of Cortés, Honduras, August – October 2004.*

4. CONCLUSIONS

The combination AA+PT+TMA gave consistently good results in both general and relative efficiency to capture *Ceratitis capitata*. These results are similar to previous studies conducted by Gazit et al [12] and Epski et al [13].

TABLE VIII. AVERAGES OF CAPTURED FLIES AND PERCENT FEMALES CAPTURED IN THE FRUIT FLY ATTRACTANTS EXPERIMENT CONDUCTED AT THE GRAPEFRUIT ORCHARD AT EL PORVENIR, ATLÁNTIDA, AGOSTO-OCTUBRE, 2004.

	Anastrepha ludens		*Anastrepha obliqua*	
Treatment	FTD[1]	% females	FTD	% females
NuLure	0.28 a[2]	61.50	0.11 b	66.11
½ AA+ PT	0.10 cd	76.82	0.03 c	68.75
¼ AA + PT[3]	0.04 de	58.33	0	.
½ AA + ¼ PT	0.11 bc	76.17	0.03 c	41.67
½ AB + PT	0.01 e	100.00	0.00 c	100.00
¼ AA + AB + ¼ PT	0.09 cd	54.17	0.03 c	64.29
¼ AB +PT	0.10 cd	93.43	0.03 c	62.50
Hog plum pulp	0.21 ab	54.62	0.23 a	53.08

[1]Flies/trap/day
[2]Means followed by the same letter are not significantly different (LSD, p=0.05)
[3]Sticky card as retention media

TABLE IX. AVERAGES OF CAPTURED FLIES AND PERCENT FEMALES CAPTURED IN THE FRUIT FLY ATTRACTANTS EXPERIMENT CONDUCTED AT THE ORTHANIQUE ORCHARD AT SANTA CRUZ DE YOJOA, CORTÉS, AUGUST-OCTOBER, 2004.

	Anastrepha ludens		*Anastrepha obliqua*	
Treatment	FTD[1]	% females	FTD	% females
NuLure	0.06 ab	45.23	0.06 b	62.12
½ AA+ PT	0.02 c	91.67	0.03 bc	70.00
¼ AA + PT[3]	0.01 c	66.67	0.00 c	100.00
½ AA + ¼ PT	0.03 bc	77.78	0.03 bc	71.43
½ AB + PT	0.02 c	40.00	0.00 c	100.00
¼ AA + AB + ¼ PT	0.03 bc	85.71	0.01 c	50.00
¼ AB +PT	0.02 c	33.33	0.00 c	100.00
Hog plum pulp	0.08 a	63.10	0.17 a	68.08

[1]Flies/trap/day
[2]Means followed by the same letter are not significantly different (LSD, p=0.05)
[3]Sticky card as retention media

Anastrepha species seem to respond better to combinations of AA+PT. In the conditions of Santa Cruz de Yojoa, where populations of *A. ludens* and *A. obliqua* are about the same size, as indicated by the total Captures of these species, the number of individuals attracted to these treatments is very similar for both species (Tables VII and IX). In 2001, at La Paz, AA+PT was statistically equal to Torula Yeast as the most efficient lures to attract *A. obliqua* (Table 3), but the relative efficiency was low, with 48.56% females. In 2002, at El Porvenir, ½AA+PT and AA+PT were statistically equal to NuLure to caPTure *A. ludens*, with good relative efficiency (Table V). In 2003, at Santa Cruz de Yojoa, ½AA+PT was statistically equal to NuLure to caPTure both species of *Anastrepha* with good relative efficiency (Table VII). In general, the best combination of AA+PT for each year caught an average of 0.29 FTP for *A. obliqua* and 0.23 for *A. ludens*, whereas the standard protein baits caught 0.39 and 0.42 FTP, respectively. The relative efficiency for these treatments was an average of 77%.

The volatiles released by the hog plum pulp performed equally or better than NuLure to attract both species of *Anastrepha* (Tables VIII and IX). However, the relative efficiency tends to be low. It may be worthwhile to conduct further studies to identify the compounds that elicit an attraction response in *Anastrepha* species.

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SYNTHETIC ATTRACTANTS FOR Anastrepha FRUIT FLIES IN MEXICO

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Abstract

The efficacy of synthetic attractants in the capture of *Anastrepha* fruit flies (*Anastrepha ludens, A. obliqua* and *A. serpentina*) was tested in three commercial orchards of known fruit fly hosts: mango (*Mangifera indica* L.), mammy (*Calocarpum mammosum* L.) and Mexican plum (*Spondias purpurea* L.) in Chiapas, Mexico. Among the synthetic attractants tested, we found that Ammonium Acetate (AA) plus Putrescine (PT) in a liquid trap was often the best combination for attracting flies. Interestingly, the reduction of release rate of AA increases the capture of fruit flies. We also found that Ammonium Bicarbonate (AB) plus PT in a wet trap was effective in a Mexican plum orchard in comparison with the other combinations of synthetic attractants. However, the synthetic attractants in dry traps were not effective and always presented the lowest Captures.

1. INTRODUCTION

The genus *Ceratitis* and *Anastrepha* involves some of the most important pests of fruit crops in America. This supports the application of Integrated Pest Management Programmes with the aim to suppress/eradicate these pests. In the field operation activities, the lures and traps used to detect and monitor fruit flies are of fundamental importance for the success of this kind of programmes. Early detection of introduced fruit fly populations is critical for effective suppression and eradication of pests. Traps are also essential for base-line data collection which allows to infer on the behavior and population ecology of fruit flies [5].

The opening of international markets for exporting fruits and vegetables and the increase in tourism are considered to be major factors influencing the increasing risk of introduction of the Mediterranean fruit fly (*Ceratitis capitata)* into Mexico [15]. This fact justifies the need for research focused on improving monitoring and detection systems. A rapid detection in the field will generally determine the type and effectiveness of the actions to be implemented [18]. Effective detection systems are essentials to prevent the establishment of pests such as fruit flies, and studies of these flies are included in the USA state and federal exotic pest detection programmes [8].

For the monitoring of fruit fly adults in Mexico, McPhail traps are commonly used by the Regional Comities of Plant Health of the federal government. Regarding this type of traps, Heath et al. (1997) [8] indicated that the use of liquid protein as a bait offer the advantage of attracting both females and males. However, when traps are checked for fruit fly catches the attractant has to be filtered often damaging the flies hindering their identification. Also when traps are serviced the attractant can spill out providing a source of attraction outside of the trap. Other factors that hinder their use include the size and weight of the trap and the fragility of the glass. Factors that influence the efficiency of a trap include: the colour [6, 9, the humidity and other climatic factors [1, 3], the contamination of bacteria [12] that affect the pH and the release of products such as amines that increase the attraction of the flies [13].

Monitoring for adult flies is carried out mainly with the use of traps that attract the insect, usually by olfactory and visual stimuli. The trapping systems combine lures with suitable devices to capture the fly upon landing. The most common lures used are sexual or food odours attractive to the flies, or a combination of these. Odours attract the fly from long distances, while colours attract from short distances, usually after arrival at the host tree or a certain part of the tree canopy.

The Joint FAO/IAEA Programme, which has long been involved in fruit fly control activities in different regions of the world transferring the area-wide Sterile Insect Technique (SIT), conducted from 1995 to 1998 a Co-ordinated Research Project (CRP) titled “Development of female medfly attractant systems for trapping and sterility assessment”with the objective to develop new synthetic medfly female attractants, and to determine their efficacy compared to proteinaceous baits under different climatic conditions, host-tree and population densities. Under this CRP a female biased medfly dry synthetic food attractant was developed and is now widely used in fruit fly operational programmes. With this background a new CRP was conducted from 2000 to 2005 focused on the development and evaluation of female biased attractants for other fruit flies. In this case the main objective was to study the specific response of various species of *Anastrepha* of economic importance in Mexico, to several types of attractants in different habitats, hosts and climatic conditions.

2. MATERIALS AND METHODS

The experiment was carried out in Chiapas, Mexico during the 2001-2004 period. Each year the protocol of research was modified according to the results obtained by all the participating countries (Table I). In all cases we used the Multilure trap (a plastic version of McPhail glass trap) as standard trap.

Study sites. In this study we used orchards of the preferred hosts of three fruit flies species: 1) Mammy (*Calocarpum mammosum* L.) which is a host of *Anasntrepha serpentina,* 2) Mango (*Manguifera indica* L.) host of Mexican fruit fly, *A. ludens*, and West Indian Fruit Fly, *A. obliqua*, and 3) Mexican plum (*Spondias purpurea* L.) host of West Indian Fruit Fly, *A. obliqua.* The description of each sites are shown in Table II.

First Year (2001). Two sites were selected for this experiment. A mammy orchard in Alvaro Obregon, and a mango orchard in Huehuetan. Trapping was carried out during two periods of four weeks in each orchard. We select six treatments which included two standard attractants, two treatments with three components and two treatments incorporating two components: 1) NuLure, 2) Ammonium Acetate, Putrescine and Trimethilammine, (AA + PT + TMA) with Triton, 3) AA +PT+ TMA with Propilen Glycol (PG), 4) AA + PT with triton and 5) Ammonium Bicarbonate (AB) + PT, with triton. Five traps of each treatment were placed and were checked twice a week. The liquid in each trap was replaced weekly. During each revision we registered the total of flies per specie and sex. We used a random block design for the test.

Second Year (2002). We used a mango orchard (two periods) and a mammy orchard (three periods), using different concentration of Ammonium Acetate. The treatments were: a) NuLure; b) ½ AA + PT; c) AA + PT; d) 2 AA + PT; e) AA + TMA+ PT; f) 2AB + PT; and g) Torula. A random block design with five replicates was used. In all traps with synthetic attractants, we used water with triton as a retention method. After each service the traps were rotated into the block. The liquid in each trap was replaced weekly. In the treatment with ½ AA + PT, the patch of AA was cover partially with aluminum tape. After four week the patch were replaced, and a new period started.

Third Year (2003). In this year we used a mammy orchard in Alvaro Obregon and a Mexican plum orchard in Frontera Comalapa, Chiapas, with four and two periods of four weeks, respectively. The treatments evaluated were: 1) NuLure, 2) ½ AA + PT, 3) ¼ AA + PT, 4) ½ AA, 5) 2 AB + PT, and 6) ½ AB + PT. A random block design with five replicates was used. In all traps with synthetic attractants, we use water with triton as a retention method, which was changed during each service. Twice a week, the traps were checked and rotated into each block. The NuLure was changed weekly. According with the research protocol, the patch of ½ AA was cover partially with aluminium tape. After four weeks the patch were replaced, and a new period started.

Fourth Year (2004). For the last year we select three orchards for the experiment. The first was a mammy orchard in Tuxtla Chico, the second was a mango orchard in Cd. Hidalgo and the last one was a Mexican plum orchard in Frontera Comalapa, Chiapas. The treatments were two hydrolyzed proteins, five wet traps with water and Triton as a retention system and a dry trap. 1) NuLure, 2) ½ AA+ PT, 3) ½ AA + PT with sticky insert, 4) ½ AA + ¼ PT, 5) ½ AB + PT, 6) ¼ AA + AB+ ¼ PT; 7) ¼ AB +PT and 8) Captor 300. The traps were checked twice at week, and the water with triton was replaced each time. Also the traps were rotated within the block. The hydrolyzed proteins were changed every week. We install five traps for each treatment in a random block design.

For the analysis, the percentage of capture was calculated and data were transformed to ln(x+1) to reduce heterogeneity of variances before using ANOVA. We used the JMP 5.0 (SAS Institute) for the statistical analysis. To compare the percent of females we used a Chisquare test.

TABLE I. TREATMENTS USED DURING EACH YEAR OF STUDY.

	Year 1	Year 2	Year 3	Year 4
1	NuLure	NuLure	NuLure	NuLure
2	AA+PT+TMA	½ AA+PT	½ AA+PT	½ AA + PT
3	AA+PT+TMA / PG	AA+PT	¼ AA+PT	½ AA + PT/Insert
4	AB+PT	2 AA+PT	½ AA	½ AA + ¼ PT
5	AA+PT	AA+PT+TMA	2 AB+PT	½ AB + PT
6	Torula Yeast	2 AB+PT	½ AB+PT	¼ AA + BA + ¼ PT
7	----	Torula Yeast	----	¼ AB +PT
8	----	----	----	CaPTor 300

AA = Ammonium Acetate, PT = Putrescine, TMA = Trimethylamine, AB= Ammonium Bicarbonate, PG = Propylen Glycol. All treatments with synthetic attractants used as a retention medium triton X-100 in water, excePT when used PG or Insert.

TABLE II. CHARACTERISTICS OF THE STUDY SITES USED FOR THE EVALUATION OF SYNTHETIC ATTRACTANTS IN CHIAPAS, MÉXICO.

Site	Host	Temp	H.R.	Luminosity	Density	Year
Huehuetan	Mango	27° C	70%	Shadow	High canopy density	2001-2002
Alvaro Obregon	Mammy	25° C	74%	Shadow	High canopy density	2001- 2003
Front. Camalapa	Mexican plum	26° C	69%	Sunny	Low canopy density	2003-2004
Tuxtla Chico	Mammy	25°C	76%	Shadow	High canopy density	2004
Cd. Hidalgo	Mango	28°C	53%	Sunny	Medium canopy density	2004

3. RESULTS

Year one. During the first year we collected in traps four fruit fly species in mango, and two fruit fly species in mammy. In mango, a total of 254 *A. serpentina* adults were captured; the best treatment was the NuLure and the worst was AB + PT. For *A. obliqua* the total caPTure was 3819 adults, the best treatments were AA + PT and NuLure with no statistical difference among them. Two other species were detected at low population levels, *A. ludens* with 81 adults and *A. fraterculus* with 35 adults. For the first specie (*A. ludens*), the best treatments were NuLure, AA+PT, AA+PT+TMA/PG and Torula with no statistical difference among them. For *A. fraterculus,* the best treatment was NuLure (Table III).

In mammy orchard two species were captured: *A. serpentina* with a total of 1202 flies and *A. obliqua* with only 108 adults. The best treatment for A. serpentina was AA+PT+TMA/PG and the trap using AB + PT had the lowest capture. For *A. obliqua* there was no statistical difference among treatments.

TABLE III. RELATIVE EFFICACY (%) FROM SYNTHETIC ATTRACTANTS FOR FRUIT FLIES IN MANGO AND MAMMY ORCHARDS DURING THE FIRST YEAR.

	Mango				Mammy	
	A. serpentina	*A. obliqua*	*A. ludens*	*A. fraterculus*	*A. serpentina*	*A. obliqua*
Total flies	254	3819	81	35	1202	108
NuLure	31.04 a	26.17 ab	22.07 a	47.18 a	14.44 ab	11.26 a
AA+PT+TMA	19.84 ab	7.92 c	6.14 b	3.23 abc	12.52 ab	10.1 a
AA+PT+TMA / PG	22.05 ab	16.34 bc	20.15 a	14.52 abc	32.14 a	26.65 a
AB+PT	4.42 b	11.13 bc	8.42 b	4.84 bc	7.09 c	13.87 a
AA+PT	13.82 ab	29.03 a	22.07 a	30.24 ab	21.36 a	24.66 a
Torula Yeast	8.84 ab	9.41 bc	21.15 a	0 c	12.45 bc	13.46 a

Means in the column followed by the same letter have no statistical significant difference ($p<0.05$)

Among the different combinations of synthetic attractants, frequently AA+PT was the best treatment. When PG was used as retention media, the three components increase the caPTure significantly in all cases. The use of AB+PT as attractant was not effective in both crops. The percent of females captured was not different among treatments in all cases ($\chi_5 < 8.18$, $p > 0.129$), except for *A. obliqua* in mango ($\chi_5 = 56.21$, $p < 0.001$). In general, the number of females captured was higher than the number of males (Table IV).

TABLE IV. PERCENT OF FRUIT FLY FEMALES CAPTURED WHEN SYNTHETIC ATTRACTANTS WERE USED IN MANGO AND MAMMY ORCHARDS DURING 2001.

	Mango				Mammy	
	A. serpentina	*A. obliqua*	*A. ludens*	*A. fraterculus*	*A. serpentina*	*A. obliqua*
NuLure	73.68	63.96	83.33	100.00	68.72	58.33
AA+PT+TMA	62.00	67.52	60.00	50.00	73.97	72.73
AA+PT+TMA / PG	60.66	71.85	81.25	66.67	64.76	65.52
AB+PT	50.00	50.36	71.43	66.67	63.74	66.67
AA+PT	55.00	63.79	55.56	91.67	69.55	70.37
Torula Yeast	68.18	59.56	88.24	---	65.73	28.57

Second Year. This year the main fruit fly species captured in mango orchards was again *A. obliqua*, with 594 flies, and *A. serpentina* in mammy orchards with 2140 captured flies. In both cases, the best treatments were the combinations of AA + PT at different rates of AA. The rest of the treatments had low caPTure. The percent of females captured showed no difference among the treatments ($\chi_6 < 7.922$, $p > 0.244$). In both sites we observed that the captures were lower when the concentration of AA increased (Table V).

TABLE V. RELATIVE EFFICACY (%) AND PERCENT OF CAPTURED FEMALES OBTAINED FROM SYNTHETIC ATTRACTANTS FOR FRUIT FLIES IN MANGO AND MAMMY ORCHARDS DURING THE SECOND YEAR.

	Mango (*A. obliqua*)		Mammy (*A. serpentina*)	
	% capture	% female	% capture	% female
Total flies	594		2140	
NuLure	6.675 d	56.82	14.20 abc	76.67
1/2AA+PT	27.305 a	57.61	21.71 a	69.87
AA+PT	24.56 ab	62.32	20.98 a	70.74
2AA+PT	21.325 abc	64.81	19.19 ab	68.74
AA+PT+TMA	6.97 cd	41.03	8.16 cd	69.89
2AB+PT	8.185 bcd	55.00	6.35 d	66.23
Torula	4.975 d	58.54	9.42 bcd	69.31

Means in the column followed by the same letter have no statistical significant difference ($p<0.05$)

Third year. In the mammy orchard we captured 2270 *A. serpentina* adults. The best treatment was NuLure followed by the combination of ½ AA+PT and ¼ AA+PT, with no statistical difference among them. The percent females captured was higher in NuLure and ¼ AA+PT than in the other treatments (χ_5 = 17.35, p = 0.004). In the Mexican plum orchard *A. obliqua* was the predominant species with a total of 787 adults, almost 50% in NuLure traps. In this case the synthetic attractants had a low capture, however, the ½ AB +PT had two times more flies than the other combinations. Again, more females than males were captured, but there was no statistical difference among treatments (χ_5 = 10.95, p = 0.052) (Table VI).

TABLE VI. RELATIVE EFFICACY (%) AND PERCENT FEMALES OBTAINED FROM SYNTHETIC ATTRACTANTS FOR FRUIT FLIES IN MEXICAN PLUM AND MAMMY ORCHARD DURING THE THIRD YEAR.

	Mexican plum (*A. obliqua*)		Mamey (*A. serpentina*)	
	% capture	% females	% capture	% female
Total flies	787		2270	
NuLure	46.77 a	53.05	38.2 a	71.51
1/2AA+PT	9.13 bc	71.83	24.7 a	69.23
1/4AA+PT	9.93 bc	63.16	20.6 a	74.71
1/2AA	7.38 c	54.55	6.4 b	62.02
2AB+PT	8.67 bc	53.03	4.8 b	62.22
1/2AB+PT	18.21 b	54.23	5.1 b	61.34

Means in the column follow of the same letter have not significant difference ($p<0.05$)

Fourth year. In this year we captured 1242 adults of *A. serpentina* in mammy orchard. The hydrolyzed proteins (NuLure and Captor) and the ½ AA + PT had more captures than the others treatments. As a dry trap the ½ AA + PT captured very few flies. In this occasion we had difference in the percent of females among treatments (χ_7 = 28.58, p < 0.001), being the best ½ AA + PT (both dry and wet) and NuLure with more than 70 % of females.

In the Mexican plum orchard, the total *A. obliqua* flies captured was of 5516 adults. The best treatments were NuLure and ½ AB + PT with no statistical difference. The percent female was above 50% in all treatments, with significant difference among them (χ_7 = 45.89, $p < 0.001$), (Table VII).

In the mango orchard, two species were captured: 21 adults of *A. ludens* and 16 adults *A. obliqua* , being the NuLure the best treatment. The analysis shows no difference among treatments for *A. ludens* (χ_6 = 5.73, p = 0.454), neither *A. obliqua* (χ_5 = 3.74, p = 0.587).

TABLE VII. RELATIVE EFFICACY (%) AND PERCENT FEMALES OBTAINED FROM SYNTHETIC ATTRACTANTS FOR FRUIT FLIES IN MEXICAN PLUM AND MAMMY ORCHARDS DURING THE FOURTH YEAR.

	Mammy		Mexican plum		Mango			
	A. serpentina		*A. obliqua*		*A. ludens*		*A obliqua*	
Treatment	% caPT.	% fem.	% caPT.	% fem.	% caPT.	% fem.	% caPT.	% fem.
Total flies	1242		5516		21		16	
NuLure	20.64 a	72.77	25.38 a	67.18	38.10 a	50.00	31.25 a	20.00
½ AA + PT	18.34 a	74.47	9.62 bc	74.12	4.76 a	0.00	18.75 a	66.67
½ AA + PT/Insert	2.01 c	73.33	3.28 d	59.47	0.00 a	---	0.00 a	---
½ AA + ¼ PT	15.55 ab	60.70	9.41 bc	74.56	14.29 a	66.67	12.50 a	50.00
½ AB + PT	8.17 b	59.35	16.78 ab	66.13	4.76 a	100.00	12.50 a	50.00
¼ AA + BA + ¼ PT	5.76 bc	66.25	8.72 c	67.50	9.52 a	100.00	6.25 a	0.00
¼ AB +PT	8.32 bc	45.21	11.85 bc	60.64	19.05 a	75.00	18.75 a	66.67
CaPTor	21.21 a	65.73	14.95 abc	71.57	9.52 a	50.00	0.00 a	---

Means in the column follow of the same letter have not significant difference ($p<0.05$)

4. DISCUSSION

Hydrolyzed protein NuLure had different efficacy when used in different host fruits. In the mango orchard NuLure was highly effective but in mammy the results were not the same. We also observed that the decomposition of hydrolyzed protein had different rates in different orchards, which may be the cause of this difference. Malo (1992) [11] indicate that the decomposition of food products affect negatively the attraction of fruit flies. The synthetic attractants performed better than the NuLure in the mammy orchards. For the four fruit fly species that responded to the traps and lures, some combination of the synthetic attractant based on AA+PT, showed to be effective. It was observed that with the three components, when PG/water was used as a retention system the Captures increased in comparison with those using Triton [16]. The PG could have a synergistic effect on the three components increasing the arrival of fruit flies to the trap.

The capture of females was similar in all the treatments (hydrolyzed proteins and synthetic food attractants), most of the time above 50%., being protein responsible for attracting more females than males [2].

In the second year the best treatments were the combination of AA+PT. The traps with three components captured less than those using AA+PT. This indicates that Trimetylamine can reduce the effect of the other two components in attracting *Anastrepha* fruit flies, as was observed by Montoya *et al*. (2002) [14]. A slow increase of capture was observed when the concentration of AA was reduced, which is consistent with reports by Epsky, 1995 [4] and Heath, 1995 [7].

In the third and fourth years the hydrolyzed protein had again the best rate of capture in the mango and mammy orchards. Interestingly, in the Mexican plum orchard the NuLure captured almost two fold the amount compared with the other treatments. The Mexican plum orchard is an habitat with low density of trees and the trees have light foliage, so the climate is warmer than in mammy orchard. Cunningham *et al*. (1978) [3] mentioned that the liquid food bait traps are more effective in dry climate than in humid climate. In the Mexican plum orchard for the first time the treatment based on AB was more effective than other combinations of synthetic attractants, including AA+PT. For this circumstance, we think that the efficacy of AB could also depend on the prevailing weather conditions. Bateman and Morton (1981) [2] stated that the attraction of AB depends on the pH level; however in this case the patch was dry, so the pH levels were not determined. The reduction of AA concentration from ½ to ¼ combined with PT did not significantly increase the attraction, so ½ AA is probably the most adequate to use in traps.

The concentration of PT had no effect on the percent of captures, so it would be possible to modify the patch to obtain a longer lasting product in the field. This would reduce handling of the trap and the costs of trapping. During the fourth year a dry trap with ½AA + PT was included, however the capture was the lowest in relation to the other treatments. It was concluded that the water is an important factor for the efficacy of the attractants.

5. CONCLUSIONS

AA+PT was consistently the best combination of synthetic attractants. The efficiency increased when the concentration of AA was reduced by half. Some of the synthetic attractants tested could be an alternative to hydrolyzed proteins, since they are at least as efficient in catching fruit flies and the costs of handling are reduced (Liedo 1995) [10]. In addition they are much more selective as they catch significantly less no target insects compared to the more generic hydrolyzed proteins. However, the synthetic attractants reduce their efficacy in dry and hot climate, thus they need to be evaluated under different climatic conditions before wide use is recommended.

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MASS TRAPPING OF Ceratitis capitata (DIPTERA: TEPHRITIDAE) IN ARGENTINA

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Abstract

One of the main objectives of Research Coordination Project (CRP) was to make improvements in control strategies using new applied technologies such as mass trapping strategies. The experimental sites were located in INTA Concordia in the northeast of the country at 31 ° 22 ' latitude South and 58° longitude West at 47.5 m over sea level. During the experimental period the rainfall, RH, temperatures and winds had been registered by the Weather Station of INTA Concordia. The use of mass trapping gave satisfactory fly control in some cases when low population densities were present. The mass trapping is an innovative alternative to the traditional ground or aerial application of toxic baits. In the present paper the results of comparative field studies on effects of attractant, trap density and deployment on the efficacy of the mass trapping methods for the control of the medfly are reported. The most promising trapping system for mass trapping is the combination of Multilure (MLT) trap and the M3 toxic bait although no statistical difference was found compared with MLT and Biolure with DDVP as retention system. These treatments showed to be as effective as the conventional control based on ground bait sprays and have the additional advantage that are more environment friendly. Additional comparative studies to assess cost-effectiveness of these treatments are required.

1. INTRODUCTION

Air and ground bait sprays, which constitute in most countries the standard control method for Mediterranean fruit fly (*Ceratitis capitata* Wied.), today, utilize a mixture of a food bait (hydrolysate protein) and a organophosphate insecticide. Although very effective when applied properly and in a timely manner, bait sprays have a number of limitations including short residual activity and undesired side effects such as the mortality of a wide range of non-target insects. The development of long-lasting attractants and retention systems in traps constitutes the main objectives of ongoing efforts to conventional fruit fly control [1].

The use of traps in a mass trapping system, gives satisfactory fly control in some cases where the fruit fly population levels are low. Traps baited with attractants and with a retention system used for fruit fly mass trapping and control is an innovative alternative to the traditional ground or aerial application of toxic baits [3]. This procedure has the advantage of not polluting the environment and protecting more the beneficial entomofauna [2]. Several types of traps are found in the market with species-specific or generic fruit fly attractants and with solid retention systems based on insecticides such as DDVP and Malathion and liquid such as water alone or mixed with compounds such as Triton and Propylen Glycol that reduce evaporation of water. In the present paper the results of comparative field studies on effects of attractant, trap density and deployment on the efficacy of the mass trapping methods for the control of the medfly are reported.

2. MATERIAL AND METHODS

From August 10 to November 9, 2001, mass trapping field tests were conducted in the Concordia area. Concordia is in the north-east part of Argentina at 31° 22’ latitude south and 58° 07’ longitude west at 47.8 m above sea level. This region has 60,000 ha cultivated mainly with navel oranges and mandarins. Argentina is the first mandarin grower of the Southern Hemisphere and the Concordia region produces 80% of the mandarins grown in Argentina. This region has very good climatic conditions for citrus. The annual average temperature is 18.5 °C, the average RH is 79% and the rainfall average is 1300 mm. During the winter temperature averages 13 °C with average minimums of 8 °C, however, temperatures are 18 °C during greater part of the day.

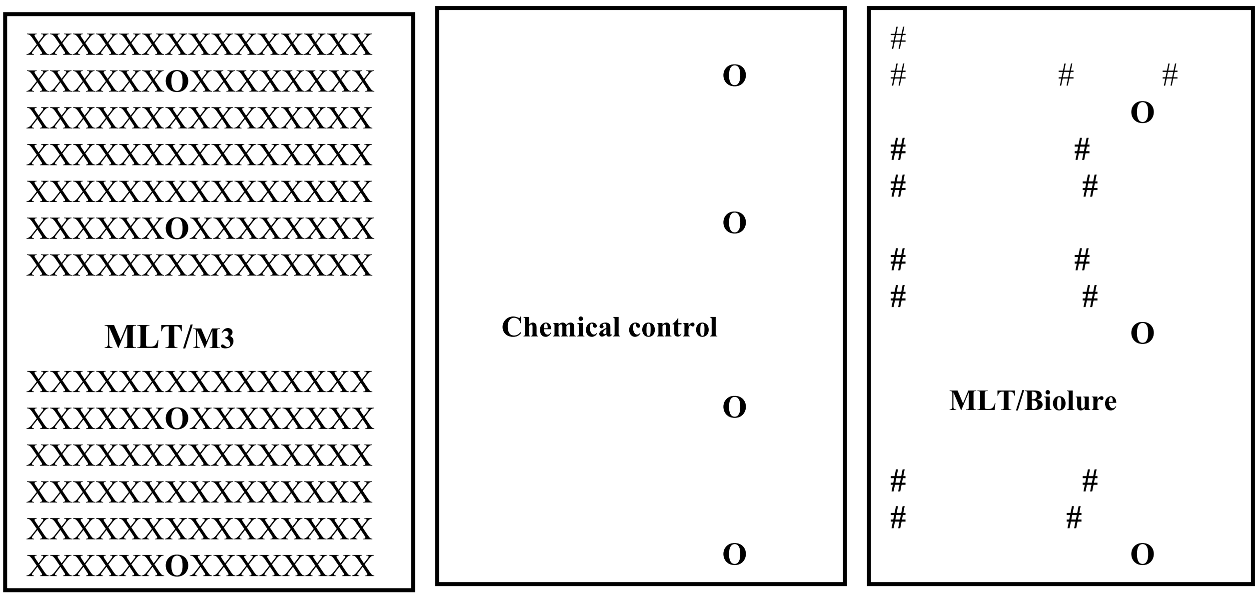
Two types of trapping systems (attractants, insecticide and retention mediums) were compared against the toxic bait used locally. The purpose of the test was to evaluate mass trapping against conventional bait sprays for control of *C. capitata* in a citrus orchard (*Citrus sinensis* var. Valencia late) in the Concordia Agricultural Experimental Station of the INTA. Percentage of fruit damage at harvest was used to evaluate the effectiveness of both control methods.

The following treatments were compared:

(a) MLT/M3. One MLT trap per tree in every tree baited with M3 (Quest Development). M3 is a toxic food attractant (plant extracts and protein hydrolysate) mixed with Lithium Perfluorooctane Sulfonate as killing agent.
(b) MLT/Biolure. Sixty traps per hectare using the MLT trap (Better World), baited with Ammonium Acetate, Putrescine and Trimethylamine (Biolure, Suterra LLC) and Dichlorvos (DDVP) tablets (Plato Industries) placed in the bottom of the MLT.
(c) Ground bait sprays (chemical control used locally) based on sugarcane molasses 5%, Malathion 100 E 0.1% and applied in alternate rows when needed.

The experimental design was a complete randomized block, with 100 trees per block and 4 replicates. The population density for each treatment was determined with Jackson traps baited with Trimedlure (TML) plugs. The Jackson traps were sampled once a week and number of flies per trap per day (FTD) was calculated. Fruit infestation level was determined through a systematic weekly fruit sampling during the test. For this purpose all fruit of the four central trees per each experimental block was harvested and dissected, and eggs and larvae recorded. Results were analyzed using a one-way analysis of variance (ANOVA) followed by LSD ($P = 0.05$) for mean separation.

2.1. Site Description



X = MLT/M3 O = Jackson traps # = MLT/Biolure

FIG 1. Layout of treatments in the orange orchard.

The Valencia late/trifoliate plot has 6.5 ha. It was planted in 1964 at 7 x 7 m., with a total of 1,326 trees (204 trees/ha). The three treatments were carried out in this plot and each one consisted of approximately two hectares, 400 trees. The rest of the trees were used as borders. The MLT/M3 traps were hung in the plot and not removed until the fruit was harvest. Under normal conditions (climatological, fruit fly pressure, etc.) the bait station will attract and kill fruit flies for a period of approximately four months. The number and timing of bait sprays in the treatment of chemical control were based on pest population densities (FTD> 0.14) and in our assay we applied bait sprays once a week when required. The MLT/Biolure using DDVP as a retention system, were hung at the beginning of the test and the attractants were replaced every 4 weeks. The DDVP was replaced every 8 weeks.

3. RESULTS AND DISCUSSION

3. 1. Pest Population Fluctuation

FIG. 2 shows the medfly population fluctuation during the field trial as indicated by the number of adults captured in Jackson traps baited with TML. The numbers of flies captured in the MLT/M3 and chemical control treatments were lower than in the MLT/Biolure treatment, with the highest level (0.62 flies per trap per day) occurring in the MLT/Biolure treatment during September. However, by the end of the study, numbers were the same in all treatments.

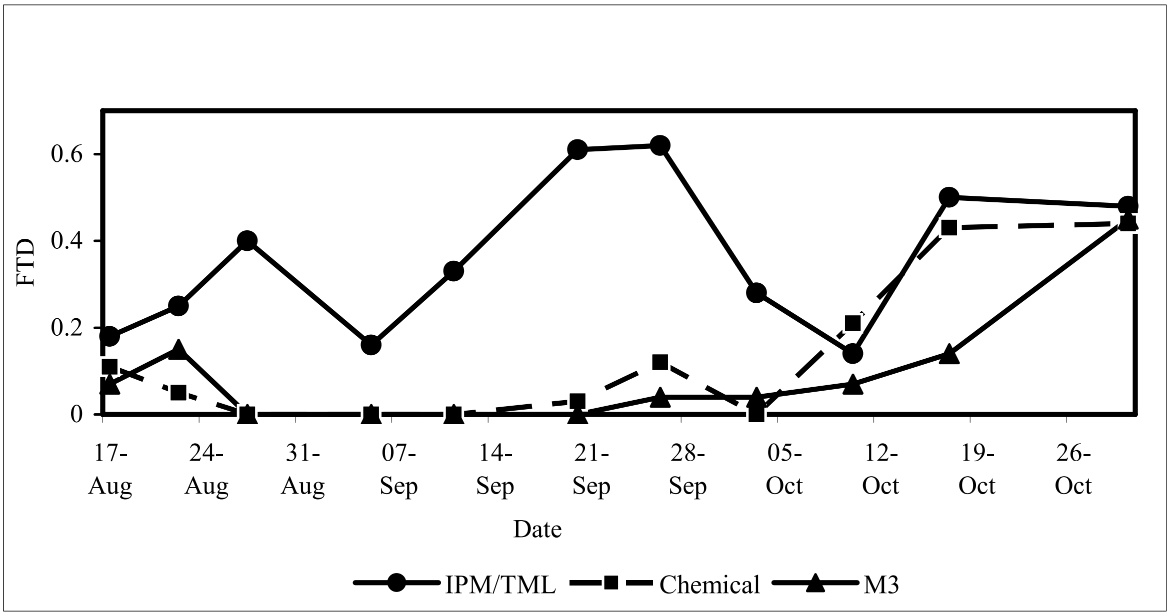


FIG 2. Population fluctuation of Ceratitis capitata in Concordia, Argentina. Year 2001.

3. 2. Damage Levels

From August 3, 2001, to previous to harvest, November 9, 2001, the fruit infestation level in the four blocks of each treatment was controlled. For this purpose all fruit of the four central trees per experimental block, were selected. The results obtained are shown in Table I.

The percent infested fruit tended to be the higher in the MLT treatments, but there were no significant differences among any of the treatments.

4. CONCLUSIONS

The mass trapping using MLT/M3 and MLT/Biolure showed similar protection to chemical control, and no significant differences in fruit infestation levels were observed. Active life of attractant and insecticide in both treatments covered the entire period of Valencia late orange susceptibility to the medfly in the Concordia area, thus provided promising alternatives to the conventional bait sprays.

TABLE I. DAMAGE LEVEL PER TREATMENT

Treatment	Number Total Fruits	Number Damage Fruit	Level of Damage (%)
MLT/M3	4348	44	1.02
MLT/Biolure	3671	57	1.55
Chemical Control	2983	39	1.31

The mass trapping method provides a potential medfly management tool that can be combined with other integrated pest management (IPM) methods used in this area. This procedure has the advantage of not polluting the environment and reducing negative impact on beneficial entomofauna. The application of mass trapping could be very important in IPM for organic fruit production.

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EVALUATION OF BAIT STATION AGAINST CHEMICAL CONTROL FOR MEDITERRANEAN FRUIT FLY *Ceratitis capitata* Wied. IN ARGENTINA

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Abstract

One of the main objectives of Research Coordination Project (CRP) was to make improvements in control strategies using new applied technologies such as bait stations. The experimental sites were located in INTA Concordia in the northeast of the country at 31 ° 22 ' latitude South and 58 ° longitude West at 47.5 m over sea level. During the experimental period the rainfall, RH, temperatures and winds had been registered by the Weather Station of INTA Concordia. A bait station (Heath Bait Station) was compared against the conventional ground bait spray using the hydrolysate protein NuLure and Malathion and against a bait spray based on Susbin bait and Malathion. Based on fruit infestation levels, the Heath Bait Station showed similar protection to Valencia orange compared with the ground bait sprays using NuLure and Susbin as attractants and Malathion. The application of bait station technology is very important in organic fruit production, and for markets that discriminate against insecticides residues.

1. INTRODUCTION

Aerial and ground bait sprays of hydrolysate protein and Malathion constitute today, in most countries, the standard control method for Mediterranean fruit fly or medfly (*Ceratitis capitata* Wied). Although very effective when applied properly and in a timely manner, bait sprays have a number of limitations including short residual activity and undesired side effects such as the mortality of a wide range of non-target insects. The development of long-lasting attractants and retention systems in traps or as bait stations constitutes the main objectives of ongoing efforts to find alternatives to conventional fruit fly control [1].

It has been shown that the use of bait stations can provide satisfactory fruit fly control. The bait station (attractant + a retention system that can be an insecticide) used for the control of fruit flies can be an innovative alternative to the traditional ground and aerial application of toxic baits. This procedure has the advantage of not polluting the environment and protecting more the beneficial entomofauna [2 and 3].

There are currently no commercial bait stations available in the market. In the present paper, results of a comparative field study carried out during 2003 and 2004 using conventional chemical control and bait stations for control of the medfly are reported.

2. MATERIAL AND METHODS

From December 12, 2003 to February 12, 2004, tests were conducted in the Concordia area. Concordia is in the north - east part of Argentina at 31° 22' latitude south and 58° 07' longitude west at 47.8 m over sea level. This region has 60,000 ha cultivated mainly with Navel oranges and mandarins. Argentina is the first mandarin producer of the Southern Hemisphere and the Concordia region produces 80% of the mandarins grown in Argentina. This region has very good climatic conditions for citrus. In winter, the average temperature is 13°C with 8°C being the minimal average temperature, however, there is 18°C during great part of the day. The annual average temperature is 18.5°C, the average RH is 79% and the rainfall average is 1300 mm. Field tests were conducted in citrus (*Citrus sinensis* var. Valencia late) in the Concordia Agricultural Experimental Station of the

Instituto Nacional De Tecnología Agropecuaria (INTA) in a citrus orchard with a high degree of isolation from other medfly host trees.

The experiment was set in a 6.5 ha orchard with the following treatments placed in 1 hectare plots:

(a) Bait station (supplied by R. Heath, USDA/ARS, Miami, FL) placed in every second tree.
(b) Ground bait sprays (chemical control used locally) based on NuLure 1 and 5 %, Malathion 100 E 0.1% and applied in alternate rows, once a week.
(c) Ground bait sprays (chemical control used locally) with Susbin bait 2%, Malathion 100 E 0.1% and applied in alternate rows, once a week.
(d) Untreated control

Medfly population densities in each plot were assessed every week by placing five Multilure traps (MLT), baited with a three component food-based synthetic lure containing Ammonium Acetate, Putrescine and Trimethylamine (Biolure) with water plus Triton added to the base of the trap to retain attracted flies. Traps were sampled daily and the number of flies captured was recorded.

Fruit was sampled once a week in all treatments to assess the infestation levels. In each treatment one hundred fruits were sampled, after that, the fruit were dissects and the larvae were put in a Petri dish and reared them to adult stage. The fruit infestation levels in each treatment over the course of the experiment are shown in Table I.

3. RESULTS AND DISCUSSION

3.1. Population fluctuation

The following figure shows the population fluctuation of medfly adults during the field test as indicated by number of flies captured in the MLT traps baited with Biolure and water plus Triton.

The total medfly captured in the plot with the Heath Bait Station was 267 adults, lower than the chemical control using NuLure as attractant with 330 adults and the chemical control using Susbin as attractant with 291 adults, during the weeks of the study. However, overall there was no statistical differences among these treatments. The highest medfly capture was in the untreated control with 643 adults, with the greatest difference starting from the 4th week of the study (FIG. 1).

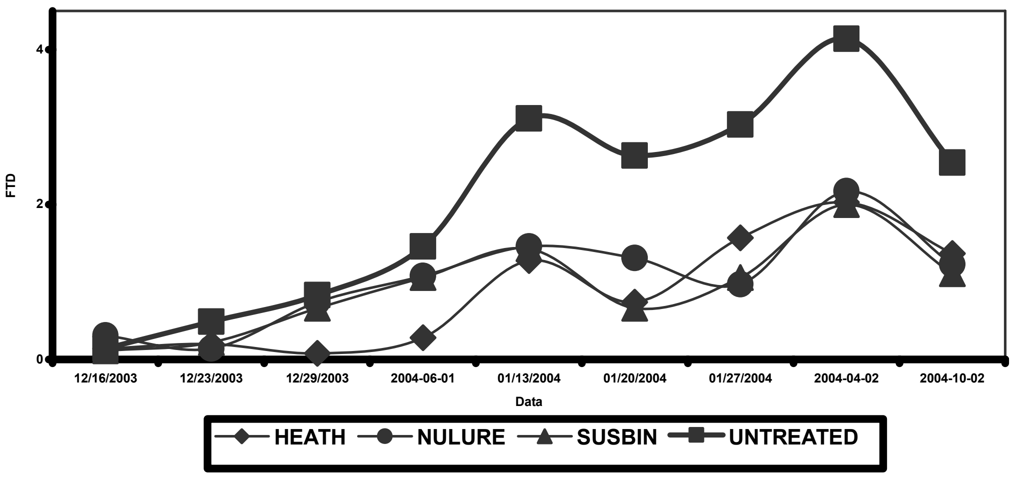

FIG.1. Population fluctuation of C. capitata *in Concordia, Argentina.*

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3.2. Damage levels

The fruit infestation levels in each treatment over the course of the experiment are presented in Table 1. Protection of Valencia orange was best when using the conventional bait spray (NuLure plus Malathion) with only 0.7% infestation. However, the bait station provided adequate protection with an infestation of 2.8% compared with the control that had 94.4% damage. These results need to be weighted against other factors such as protection of the environment and possibilities to compete in higher value markets.

TABLE I. DAMAGE LEVEL PER TREATMENT.

Treatment	Number of Total Larvae	Level of Damage (%)
Nulure + Malathion	1	0.7
Susbin + Malathion	3	2.1
Heath Bait Station	4	2.8
Untreated Control	134	94.4

4. CONCLUSIONS

The Heath Bait Station showed similar protection compared with chemical control based on NuLure and chemical control based on Susbin. Based on fruit infestation levels it can be said that these three treatments protected the orange orchard from infestation throughout the fruiting season. The untreated plot showed high infestation in the sampled fruits. This as a result of high population of *C. capitata* in Concordia and the high susceptibility of Valencia late orange to medfly infestation.

Bait stations provide a useful medfly management tool when combined with other IPM methods used in this area. This procedure has the advantage of not contaminating the environment and greater protection for beneficial entomofauna. The application of bait station technology is very important in organic fruit production, and for markets that discriminate against insecticides residues.

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RESPONSE OF *Anastrepha* SPECIES (DIPTERA: TEPHRITIDAE) TO SYNTHETIC ATTRACTANTS IN COLOMBIA

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Abstract

Efficient trapping systems for *Anastrepha spp* is an essential requirement for integrated fruit fly management. In order to find more efficient attractants for this genus, food-based attractants were tested in two orchards in Colombia against *A. obliqua*, *A. striata* and *A. fraterculus* populations. Six experiments were carried out from 2001 to 2004, four of them were done in a mango orchard and the other two in a coffee plantation. The synthetic food attractants tested were different combination of Ammonium Acetate (AA), Putrescine (PT), Ammonium Bicarbonate (AB) and Trimethylamine (TMA); the controls were NuLure and Torula. Attractants were placed in Multilure® traps using equidistant spacing of 28 m. Trap catches were recorded twice per week for a total of eight weeks. Traps were serviced once per week and rotated after each service. The experimental design was random blocks with five repetitions. In experiments 1, 2, 3, 5 and 6, NuLure and Torula were statistically the best attractants, however, synthetic lures caught more flies than the controls in the fourth one, when climate was hot and dry: 1/2AA+PT, ½AB+PT and ¼AB+PT were the best attractant for males of *A. obliqua* and ½AA+PT and ¼AB+PT were the best for females. In some repetitions the synthetic lures capture more or equal numbers of flies than the controls, perhaps when in the previous days the weather was hot and dry. Attractants in general caught a larger number of old females than young or mature females in the first tests, but the mature females were predominant in the fourth one when the synthetic attractants showed to be better. Fruit flies showed different response to attractants depending on sex, species and climatic conditions. More studies are needed in order to improve trapping systems for *Anastrepha*.

1. INTRODUCTION

Insect surveillance programmes are an important part of the decision making on actions to apply to control an insect pest. Surveillance of a pest provides information on insect activities such as invasion, migration, local movements, feeding and reproduction [1]. For area-wide Sterile Insect Technique (SIT), trapping systems need to be accurate in order to assess the pest population level before sterile insect releases begin. Trapping systems are also important to assess the impact of the suppression and eradication methods and to survey the area following eradication [2].

Ammonia is used by several species of fruit flies to locate food or oviposition resources [3, 4, 5, 6]. Different sources of ammonia have been studied as fruit fly attractants: proteins, emissions from bacteria, feces, urine and recently dry synthetic food lures [6]. Synthetic food lures have shown to be efficient particularly for monitoring of female medflies [2, 7, 8, 9, 10, 11], and have shown to be attractive also for *Anastrepha ludens* and *A. suspensa* [6].

The efficiency of SIT for suppression and eradication of medfly or other fruit flies species is well known, including several species of *Anastrepha*, particularly *A. ludens* [12]. The genus *Anastrepha* is one of the most important fruit fly pests in Latin America. In order to expand the use of area-wide SIT against other *Anastrepha* species, rearing techniques and trapping systems must be improved.

In this paper the results obtained from a set of experiments conducted as part of the Coordination Research Project (CRP) of the International Atomic Energy Agency (IAEA) are presented. The objective of the CRP was to study female biased dry synthetic food attractants for a wide range of fruit fly species, including *Anastrepha* spp, under different climatic conditions.

2. MATERIAL AND METHODS

Six experiments were carried out from 2001 to 2004. Four of them in a mango orchard and the other two in a coffee plantation (Table I). In Colombia, mango is the main host of *A. obliqua* and coffee of *A. fraterculus*. However, *A. striata* were also captured in traps.

TABLE I. CLIMATIC CONDITIONS PREVAILING DURING THE EXPERIMENTS IN COLOMBIA, 2001-2004.

Experiment	Host	Date (start and finish)	Temp. °C (average)	RH% (average)	Precip. mm (total)
1	Mango	03/23/01 05/14/01	28,19	73,57	206,1
2	Mango	03/31/03 05/22/03	28,19	72,18	331,2
3	Mango	09/11/03 03/11/03	28,27	71,52	205,90
4	Mango	08/13/04 10/05/04	29,65	61,37	201,6
5	Coffee	02/26/04 04/19/04	--	--	--
6	Coffee	10/20/04 12/11/04	--	--	--

The mango orchard is located in the Nataima Research Center of CORPOICA (National Research Institute). Nataima is located in the Bogotá – Ibagué road, km. 150, 4° 11´ 33.695" North, 74° 57´47.200" West and 387 meters over the sea level. The average temperature is between 25 and 28 °C, and 68% of RH; it has an annual rain fall of 1300 mm. Tests were carried out in a mango orchard of 9.5 ha and 14 year old trees. In the surrounding area there are orchards and individual trees of mango, citrus, guava, plum, papaya and others. Daily climatic data were obtained from the Research Center's meteorological station.

The coffee orchard is located in Ibagué, at 1400 meters over sea level with an average temperature of 22°C and 75% of RH and 1800 mm of rain fall. In the surrounding area there are trees of inga, guava, citrus and cassava. In this case there was no meteorological station available in the area.

The NuLure and Torula yeast were used as standard attractants and they were compared with different combination of the dry synthetic food lures Ammonium Acetate (AA), Putrescine (PT) and Trimethylamine (TMA) and with other local products. The combination of the synthetic lures varied from one test to the other in order to find the best results (Table II).

Traps were hang in the upper two thirds of the south- eastern part of the host tree canopy and 28 meters away from any other trap. Tests were run for eight weeks, i.e. for 56 days, and traps were checked and data collected twice a week.

NuLure and Torula were replaced every week and the synthetic lures every four weeks. Traps within a block were rotated sequentially after each check when a randomized block design was used. Experiments began when the first fruits were ready for harvest and the fly population started to increase; this was different in the fourth test that began before ripe fruits were available and thus populations were low.

In the first test (2001) the experimental design used was Latin Square with six treatments. In the other experiments a random block with five replicates and with the treatments shown in Table II was used. For each trap check the total number of males and females and grand total for each species was recorded.

Data were analyzed using a statistical programme (SANEST – ESALQ/USP). The analysis of variance (ANOVA) was performed on transformed data (square-root of each value plus 0.5) and followed by a Duncan test to assess the statistical difference. The analysis was performed for total Captures and for Captures of males and females for each species.

Samples of females captured in traps were obtained after each trap check in order to know their developmental stage. Ovaries were dissected and studied under the microscope. Young females have undeveloped ovaries, mature females have developed ovaries and a large number of eggs and old ones have developed ovaries but without or with few eggs.

3. RESULTS

In the first experiment, 5.711 fruit flies (2.693 males and 3.018 females) were captured belonging to three species: *A. obliqua* (5.104 flies; 2.390♂ and 2.714♀), *A. striata* (429; 262♂ and 167♀) and *A. sororcula* (26♀). The other 152 specimens could not be identified because they were damaged. Statistical analysis was conducted for male and female Captures of *A. obliqua* and *A. striata* in this case for total Captures and for *A. obliqua* by checks. NuLure was the best treatment follow by Torula and they were better than the synthetic attractants (FIG. 1).

The capture of females and males was different depending on the species. The number of females of *A. obliqua* collected was slightly higher than males, however, for *A. striata* it was the opposite. In both cases there was no statistical difference in female-male Captures (FIG. 2). A total of 2.436 females were dissected in order to know their developmental stage resulting in 68.6% being old females (Figure 6). More old females than young or mature were collected in all treatments except in the AB+PT treatment that caught younger females (FIG. 6).

In the second experiment, a total of 14.655 fruit flies were caught, 7.493 females and 7.162 males. Only 11.411 specimens were identified, 11.082 belonged to *A. obliqua* and 329 to *A. striata*. The NuLure (5.357 flies) was the best treatments, followed by Torula (3.401) for both *A. obliqua* and *A. striata* species (FIG. 1). Among the different AA + PT treatments, the capture was similar and statistically different than the best treatments (NuLure and Torula). The poorest treatments were AB + P and the optional treatment (Ammonium phosphate). There are, however, some interesting findings when analyzing the results for each trap check. In the case of *A. obliqua*, no statistical difference for female Captures was found comparing all treatments in the case of the data corresponding to checks 1 and 12. The same was true for males in checks 1, 8, 9 12 and 14. For total Captures (males and females) no difference was found between NuLure and some of the synthetic AA+PT based attractants in at lest six of the trap checks (FIG. 3).

In the second experiment, 3.149 females of *A. obliqua* were dissected. In this case, in general, 52% of them were mature females and 40% were old females. With NuLure, 2AB+PT and Ammonium Phosphate treatments, the number of old females was higher than young or mature females. In the AA+PT based treatments and Torula, the number of mature females was higher. In the first test more old than mature females were captured in Torula (FIG. 6).

In the third experiment, a total of 29.073 fruit flies were caught, 15.300 females and 13.773 males. *Anastrepha obliqua* was the predominant species (only 22 specimens of *A. striata* were caught). The NuLure (10.062 flies) and Torula (8.162) were the best treatments (FIG. 1) with no statistical difference between them. All other treatments had a poor performance and fruit fly Captures were similar. The population was very high at this time of the year (September to November) when the mango season starts and susceptible fruits are available for infestation.

No statistical difference for females was found in trap checks number 4, 5 and 7 and for males in checks 4, 5, 6, 7 and 9. For total Captures (males and females) synthetic attractants were equal to NuLure in at lest five checks (FIG. 4).

In this experiment, 4.595 females were dissected and 60% were mature females. In contrast to the previous tests, the number of young females was significant (34%). In all treatments the number of mature females was higher than old females (FIG. 6).

TABLE II. TREATMENTS USED IN THE SIX EXPERIMENTS CONDUCTED IN COLOMBIA FROM 2001 TO 2004.

Num. of test	Date	Traps	Retention	Treatments							
				A	B	C	D	E	F	G	H
1	03/23/01 05/14/01	Multilure	Water	NuLure					Torula		
		Multilure	Water + Triton		AA+PT+TMA		AB+PT	AA+PT			
		Multilure	Polygenglycol			AA+PT+TMA					
2	03/31/03 05/22/03	Multilure	Water	NuLure						Torula	Ammonium phosphate
		Multilure	Water + Triton		1/2AA+PT	AA+PT	2AA+PT	2AB+PT	AA+PT+TMA		
3	09/11/03 03/11/03	Multilure	Water	NuLure						Torula	
		Multilure	Water +Triton		½ AA + PT	¼ AA +PT	½ AA	2AB + PT	½ AB + PT		
4	08/13/04 10/05/04	Multilure	Water	NuLure							
		Multilure	Water +Triton		½AA + PT		½ AA + ¼ PT	½AB + PT	¼AA + AB + ¼PT	¼AB+ PT	
		Multilure	Sticky insert			½AA + PT					
		Insect trap	Water								Nulure
5	02/26/04 04/19/04	Multilure	Water	NuLure						Torula	
		Multilure	Water +Triton		½ AA + PT	¼ AA +PT	½ AA	2AB + PT	½ AB + PT		
6	10/20/04 12/11/04	Multilure	Water	NuLure							
		Multilure	Water +Triton		½AA + PT		½ AA + ¼ PT	½AB + PT	¼AA + AB + ¼PT	¼AB+ PT	
		Multilure	Sticky insert			½AA + PT					

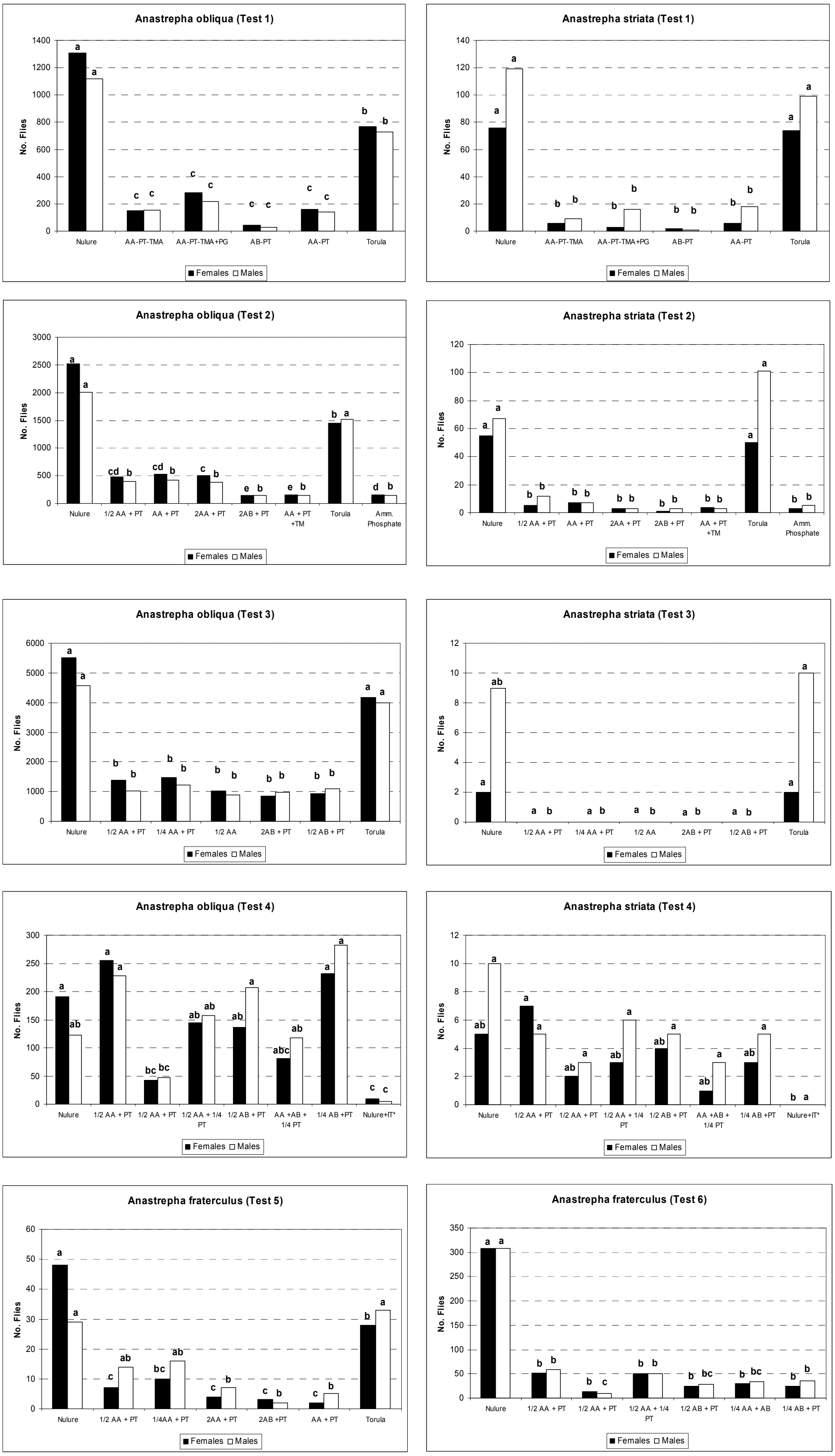

FIG. 1. Number of females and males for each fruit fly species captured in different trapping systems (traps, attractants and retention mediums) and in two localities in Colombia from 2001 to 2004.

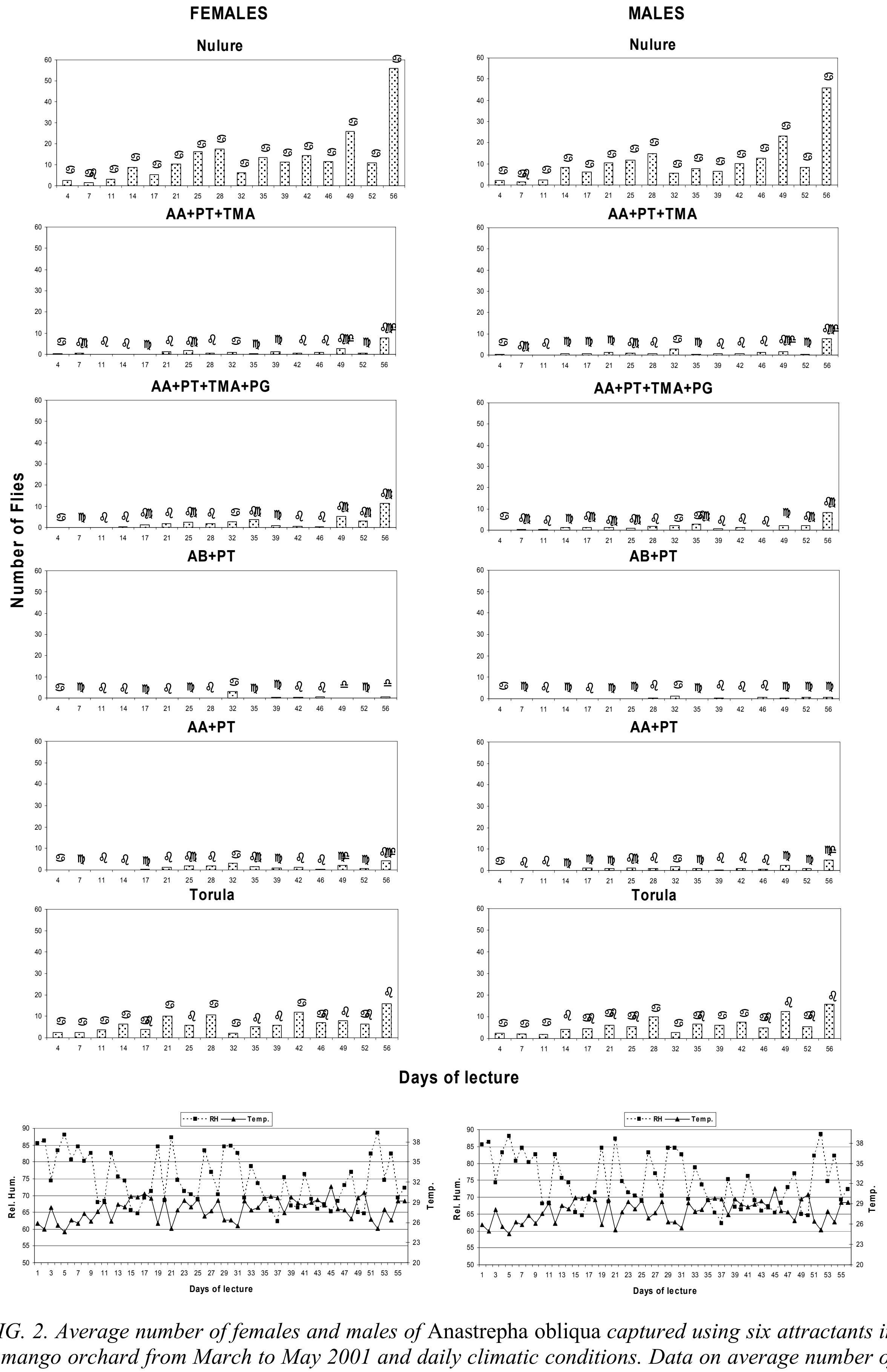

FIG. 2. Average number of females and males of Anastrepha obliqua *captured using six attractants in a mango orchard from March to May 2001 and daily climatic conditions. Data on average number of flies has to be read vertically for each trap check.*

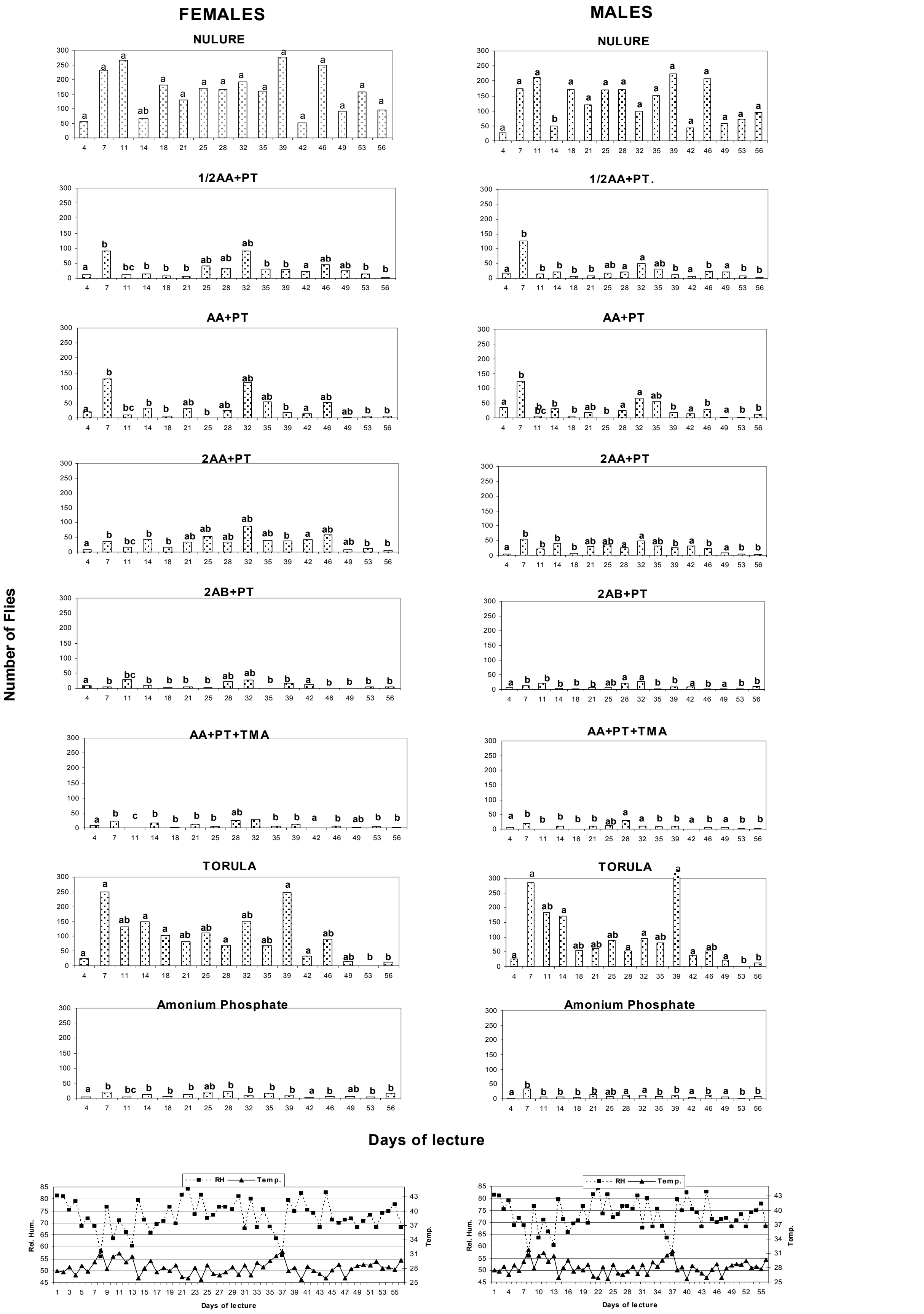

FIG. 3. Average number of females and males of Anastrepha obliqua *captured using eight attractants in a mango orchard from March to May of 2003 and daily climatic conditions. Data on average number of flies has to be read vertically for each trap check.*

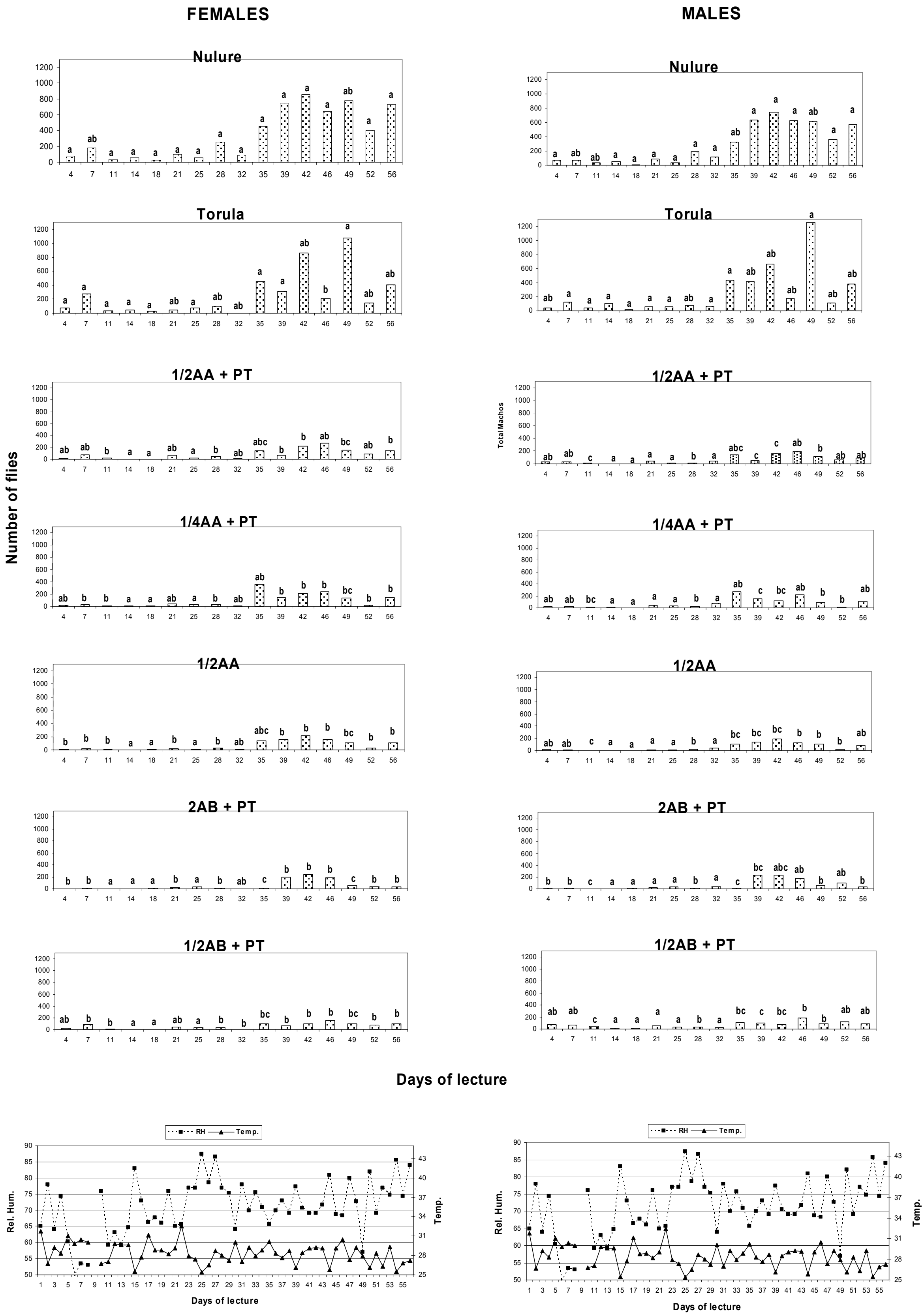

FIG. 4. Average number of females and males of Anastrepha obliqua *captured using seven attractants in a mango orchard from September to November of 2003 and daily climatic conditions. Data on average number of flies has to be read vertically for each trap check.*

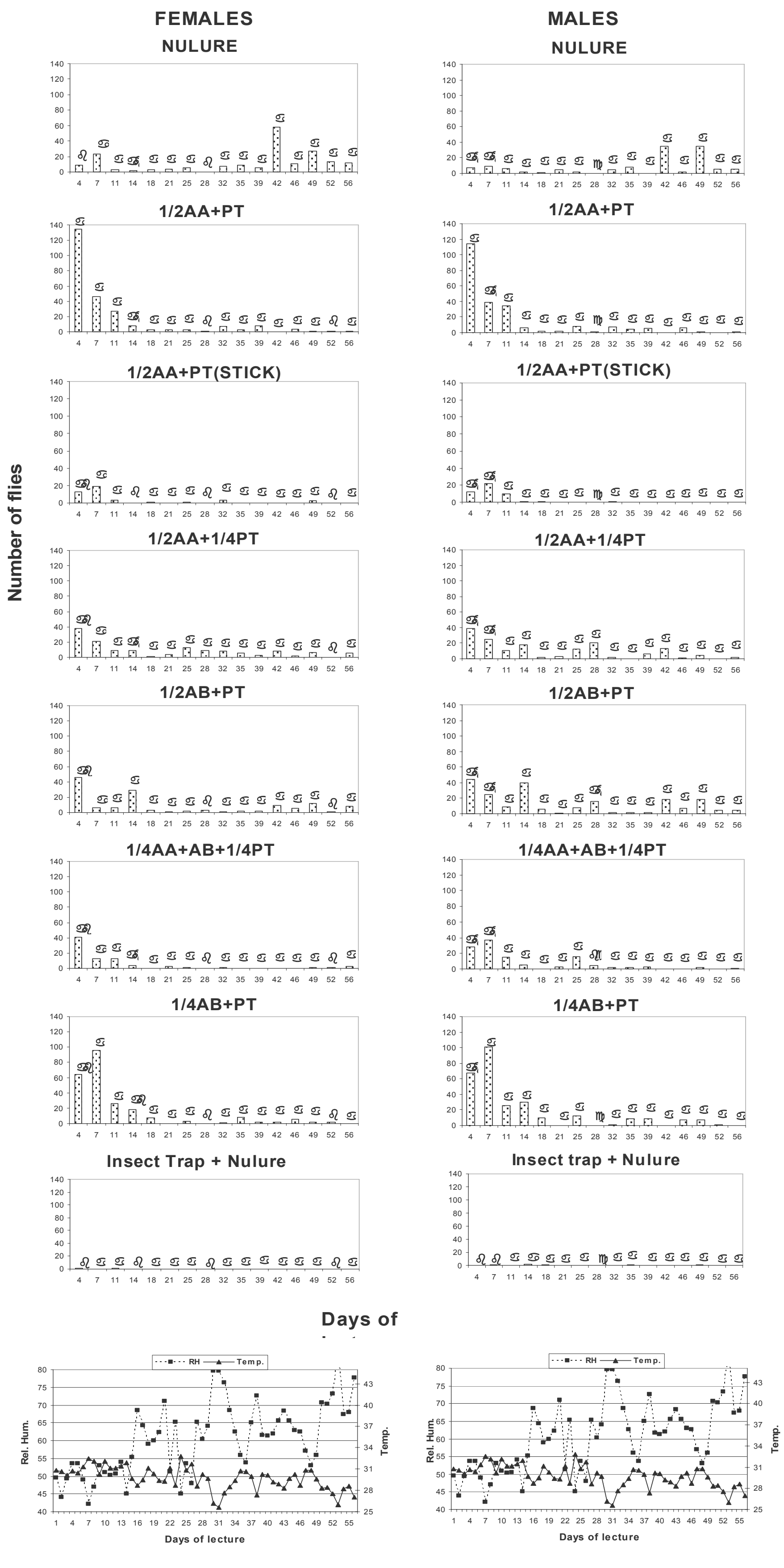

FIG. 5. Average number of females and males of Anastrepha obliqua *captured using eight attractants in a mango orchard from August to October of 2004 and daily climatic conditions. Data on average number of flies has to be read vertically for each trap check.*

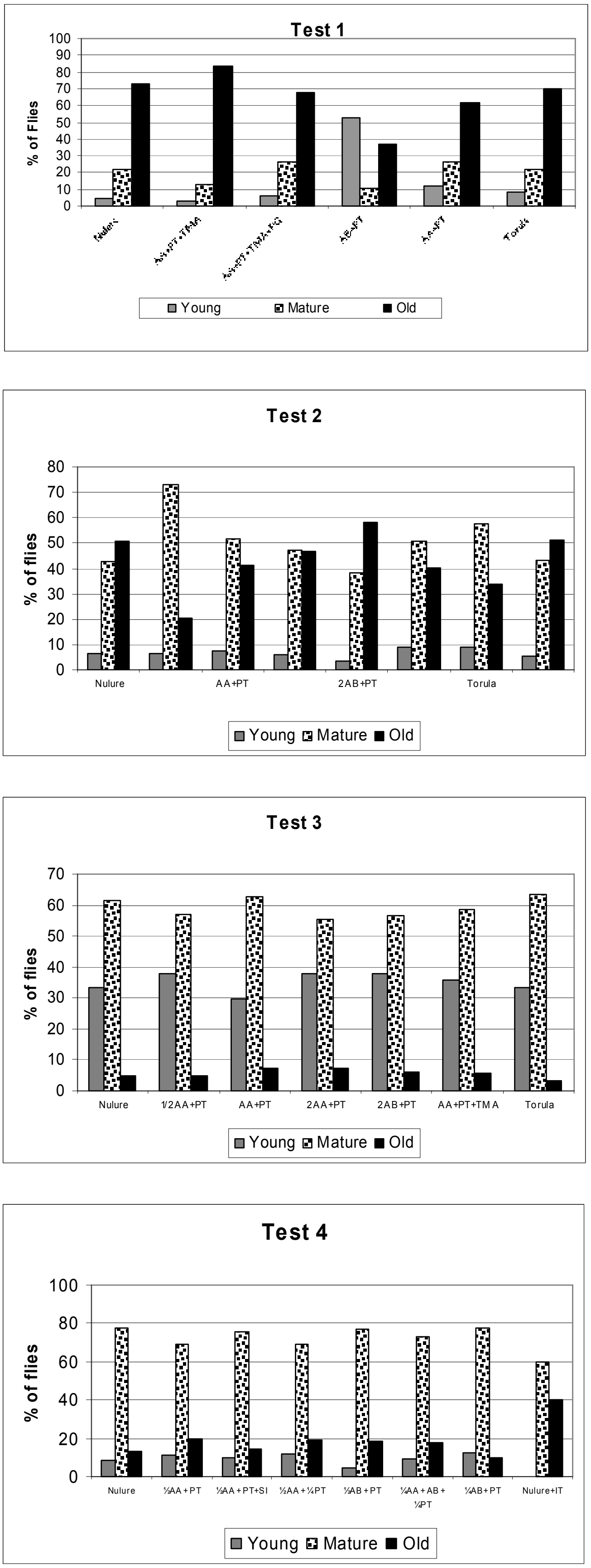

FIG. 6. Percentage of young, mature and old A. obliqua *females captured in traps using different attractants from 2001 to 2004 in Colombia.*

In the fourth experiment a total of 2.304 fruit flies were caught, with 2.260 *A. obliqua* and 62 *A. striata*. The total number of females was 1.096 (1.071 *A. obliqua* and 25 *A. striata*) and 1.226 males (1.189 *A. obliqua* and 37 *A. striata*). ½AA+PT, ½AB+PT and ¼AB+PT were the best attractants for *A. obliqua* males and NuLure, ½AA+PT and ¼AB+PT for females with no statistical difference among these treatments. NuLure was the best treatment for *A. striata* (FIG. 1).

The statistical analysis performed for each check only showed difference for females in checks 1, 4, 8 and 15 and in checks 1, 2 and 8 for males. However, for total Captures (males and females) the synthetic attractants were statistically similar to NuLure (FIG. 5). NuLure was the best attractant for females only in check 14.

A total of 946 females of *A. obliqua* were dissected and the highest number (73%) was for the mature females. The number of young and old females was similar. In all treatments, including NuLure, the percentage of mature females was higher than young and old females (FIG. 6).

In the fifth experiment, the population was low. Only 216 (115 females and 99 males) fruit flies were captured in the traps, all were *A. fraterculus*. The best treatments were NuLure (77 specimens) and Torula (61) with no statistical difference between them followed by AA+PT. ½AA and AB+PT were the worse treatments. In this experiment no analysis was conducted by checks since there were many traps with zero insects.

In the sixth experiment, 1.029 fruit flies were trapped all *A. fraterculus*. 502 of them were females and 527 were males. NuLure (616 flies) was consistently the best treatment catching more total flies as well as more female flies compared to the rest.

4. DISCUSION

Results found in our studies suggest that, in general, the synthetic food attractants used in these tests are not statistically better than NuLure and Torula yeast for monitoring *Anastrepha* species under the hot and humid climatic conditions prevailing in this part of Colombia, which can be characterized as tropical. However, there are some indications that combinations of AA and PT could be used under certain conditions. During the fourth experiment, climatic conditions were hotter and dryer as indicated in Table I and the synthetic food attractants performed well being the best treatment ½AA and PT.

There are a number of factors that influence the response of fruit flies to attractants. These are: species, sex, age, feeding history and adult diet [6, 13, 14]. No specific studies have been done to measure the effect of climatic conditions and efficiency of fruit fly attractants. Through findings in this and other experiments it is clear that climate plays an important role on the efficiency of trapping systems [13, 16].

When relative humidity (RH) was near or under 65% and the maximum temperature was above 29 ^{o}C in previous days, the best treatments were the synthetic food attractants. However, when RH in previous day increased and temperature decreased the best treatments were in general the hydrolysate protein NuLure and Torula yeast. For experiments five and six climatic conditions were not registered, however, these were carried out in a coffee orchard where climatic conditions were cool and humid in contrast with the other experimental sites. Under these conditions, the synthetic lures performed poorly. One possible explanation is that the rate of emissions of volatiles from the synthetic lures are higher under dry and hot conditions or that the efficiency of the emission of volatiles from NuLure and Torula decreased under these conditions.

This trend can clearly be seen graphically although given that apparently small variations in climate affect the performance of the attractants, more detailed research is required in order to be able to model the results.

Age structure of the population can also have a significant influence on the response of fruit flies to traps. The performance of the synthetic attractants was worse in the first experiment than in others. This could have been influenced by the age of the flies that were trapped. Old females were captured in the first experiment, in contrast with the fourth one in which more mature females were captured. The age of the flies captured in the different experiments suggest that the population age structure is different depending on the time of the year when the experiments are being conducted. Studies on fruit fly population dynamics are normally done for short periods of time thus the real population fluctuations and structure are not well known for the *Anastrepha* species [17, 18]. From these findings one could infer that, in part, the response of fruit flies to the attractants varies according with the age structure and the population level at a given time.

5. CONCLUSIONS

More studies need to be done in order to understand more about the influence of climate, age structure of fruit fly populations and population levels on the response of *Anastrepha* fruit flies to food attractants in tropical conditions.

For *Anastrepha* surveillance, it appears that dry synthetic food lures perform better under dry and hot climatic conditions and that liquid hydrolysate protein and Torula Yeast perform better under cooler and more humid conditions.

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PRELIMINARY RESULTS OF BAIT STATION EVALUATION FOR MEDFLY IN A CITRUS ORCHARD IN COSTA RICA

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Abstract

The objective of the present study was to test the effectiveness of bait stations for suppression of medfly (*Ceratitis capitata,* Wied.) populations. The evaluation was carried out at La Guácima orchard, a 1.4 ha sweet orange orchard, from January 20 to March 17, 2005. Fifty bait stations were placed every week for 24 hrs in the experimental orchard. The data obtained were compared with the medfly population at a mixed fruit orchard (Vargas Orchard) of 0.4 ha located 1.0 km to the east of the first one, and with another 0.8 ha citrus orchard (Ruiz Orchard) located in Santa Ana where no control measures were applied. Fortyone medflies were captured at La Guácima Orchard, 314 at Vargas Orchard and 552 at Ruiz Orchard. Also captured were 3 *Anastrepha ludens* at La Guácima Orchard, 15 *A. ludens* and 1 *A. fraterculus* at Vargas Orchard and 8 *A. ludens* and 1 *A. obliqua* at Ruiz Orchard. The fly per trap per day index (FTD) at La Guácima Orchard oscillated between 0.04 and 0.2, and there were no medfly larvae in 8 samples of 50 mature oranges analyzed weekly. At Vargas Orchard, the FTD index oscillated between 8.5 and 20.5 and at Ruiz Orchard between 0.16 and 35.16. The results show the potential of the bait stations to control medfly populations in a sweet orange orchard during the dry season, period when the medfly population density in Costa Rica increases.

1. INTRODUCTION

Orange production constitutes an important source of nutrition, income and work in Costa Rica. The cultivated area increased from 15,000 ha in 1982 to 26 000 ha In 2005. This area corresponds to 4.5 million trees and a production in 2004 of 367 000 MT. There are approximately 4,000 producers in the country. (SEPSA - MAG. In: Barquero, M. 2005).

The bioclimatic conditions of the country favors the presence of a rich biodiversity, and a large quantity of pests that attack the agricultural products.

Oranges are not an exception. In Costa Rica this crop is attacked by several pests, from viruses to vertebrates. The fruit flies of the family Tephritidae are pests of special importance.

Since its arrival in Costa Rica in 1955, the medfly *Ceratitis capitata* (Wied.), has infested citrus fruits. producing important losses in certain regions (Gutiérrez, J. 1975). For this reason there is interest in reducing the population density and the damages that it produces.

Most of the 26,000 ha orange crop area under cultivation is located in the northern region, a zone with rich biodiversity, large areas dedicated to conservation, and with a special interest in reducing the drain of genetic resources.

For these reasons, the development and evaluation of low environmental impact strategies to control these pests are required. The application of bait stations can be one of those important strategies.

The present research had the objective of evaluating bait stations to prevent the increase of medfly populations in a citrus orchard with ripe fruit about to be harvested.
Previous studies carried out by Camacho [1] in this same citrus orchard and by Hedstrom [2] in a nearby site, demonstrate that in this region the medfly population begins to increase between December and January, when the dry season and the orange summer crop starts in the country.

This report presents a preliminary evaluation of the use of the bait stations to control the increase of the population density of the medfly in a sweet orange plantation. This research is part of the Coordinated Research Project entitled "Development of Improved Attractants and their Integration into Fruit Fly SIT Management Programs" of the International Atomic Energy Agency (IAEA) that was conducted in Costa Rica from 2000 to 2005 and several other countries with the support of the United States Department of Agriculture (USDA) and private companies that supplied the bait station and trapping materials.

2. MATERIAL AND METHODS

2.1. Experimental area

The evaluation was carried out in a sweet orange plantation (*Citrus sinensis*), located in La Guacima District, Alajuela Canton, in Costa Rica. (FIG. 1).

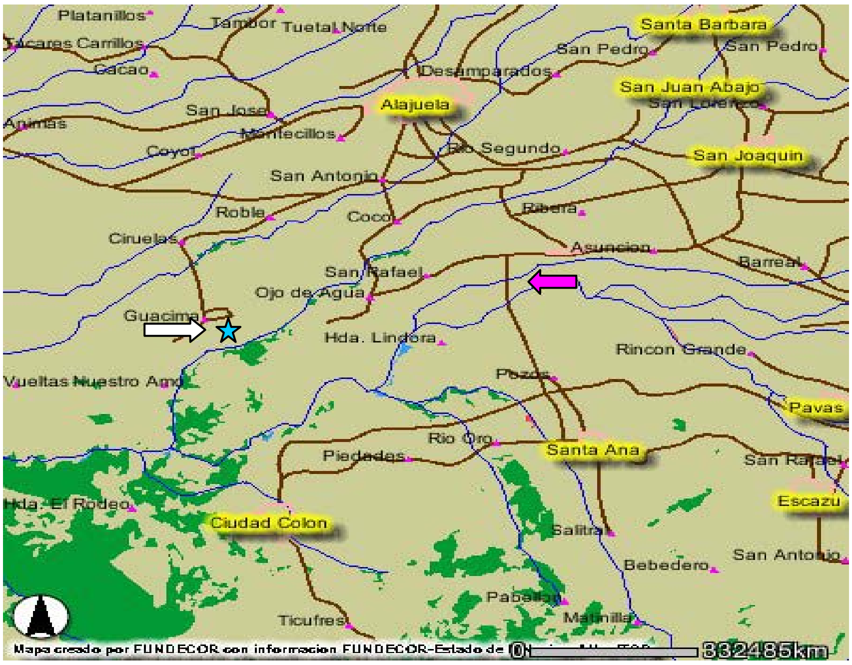


FIG. 1. Geographical location of La Guácima citrus plantation (white arrow on the map), Vargas Orchard (gray star) and Ruiz Property (black arrow) at Alajuela and Santa Ana Cantons, Costa Rica.

La Guacima Orchard is a 1.4 ha orange plantation which is located in the La Guacima District and whose geographical coordinates in the center of the property are: latitude N 09° 56' 11.3" and longitude W 84° 16' 22.7". The orchard has 18 rows, separated from each other by 8m with distance between tress of 4m. . Most of the rows have 25 trees.

2.2. Comparison of population levels among orchards

The variation of the medfly population levels was measured in two other fruit orchards. One citrus orchard located in Santa Ana (Ruiz Orchard) and another (Vargas Orchard) with a mix of fruits located 1km to the east of the experimental orchard.

Ruiz Orchard is 0.6 ha citrus orchard located in Santa Ana, with predominantly sweet orange trees (*Citrus sinensis*), with four tangerine trees (*C. reticulata*) and five mango trees (*Mangifera indica*). This plantation is surrounded by grapevine fields on the north and west side, and large storage cellars on the east side.

Vargas Orchard is a 0.4 ha plantation located 1km to the east of La Guácima Orchard. This is a complex orchard with 3 sweet orange trees (*Citrus cinensis*), 4 grape fruit trees (*C. paradasi*), two tangerine trees (*C. reticulata*), two caimito trees (*Chrysophylum caimito*), two sapota trees (*Manilkara achras*), two cas trees (*Psidium friedristhalianum*) and two guava trees (*P. guajava*), with three mango trees (*Mangifera indica*) and one pink apple tree (*Syzigium jambos*). All these fruits are hosts of the medfly and other tephritids of the *Anastrepha* genus. The first four species mentioned above had ripe fruit during the evaluation period.

2.3. Experimental period

The experimental period consisted of two phases:

A preliminary phase was carried out from 6 to 17 of January, 2005. In this period, Multilure traps (MLT) baited with Biolure (Ammonium Acetate (AA), Putrescina (PT) and Trimetilamina (TMA)) were placed in the orchards to determine the presence of the medfly. There are no data from this phase for the Vargas Orchard because all the traps were lost.

Once the presence of the medfly in these areas was confirmed, the second phase began. This was from January 20 to March 17, 2005.

2.4. Bait stations and trapping systems

The bait stations were developed and supplied by Bob Heath from the USDA/ARS laboratories in Miami, Florida. Fifty bait stations (36 bait stations/ha) were placed at La Guácima Orchard. These were distributed as indicated in FIG. 2, one every third orange tree.

The traps were used to monitore the medfly population levels in the orchards. They were placed on Thursdays at 10:00 am and were collected the following day at the same hour (24 hrs of exposure). Each trap was located on the southeast side of each tree, 2.5m above the ground. Five MLT traps were placed at La Guácima Orchard, these having been baited with the three component attractant Biolure. At Vargas Orchard, 5 traps were placed baited with the same attractant.

The collected flies were taken in glass vials with 60% alcohol to the fruit fly laboratory of the Biology School, University of Costa Rica, where they were identified and counted.

All data on fruit fly catches are expressed using the population index flies per trap per day (FTD).

To complement the data obtained through trapping, 50 oranges were collected per week at the Ruíz and La Guácima orchards and were analyzed by dissection to determine the presence of fruit fly larvae. This evaluation was not carried out at Vargas Orchard.

3. RESULTS

Apart from medfly, other species were captured, mainly of the genus *Anastrepha* spp. (*A. ludens, A. fraterculus* and *A. obliqua*).

During the experiments, 41 medflies were captured at the La Guácima orchard, 314 at Vargas orchard and 552 at Ruiz orchard. Two specimens of *A. ludens* were also collected at La Guácima orchard, 15 *A. ludens* and 1 of *A. fraterculus* at Vargas orchard and 8 *A. ludens* and 1 *A. obliqua* at the Ruiz orchard.

The quantity of flies collected indicates two important aspects:

(1) The density of the medfly population in La Guácima orchard consistently stayed low (compared with that of the other two sites) and
(2) The density of the medfly population in this orchard never increased significantly. (FIGS. 2, 3 and 6).

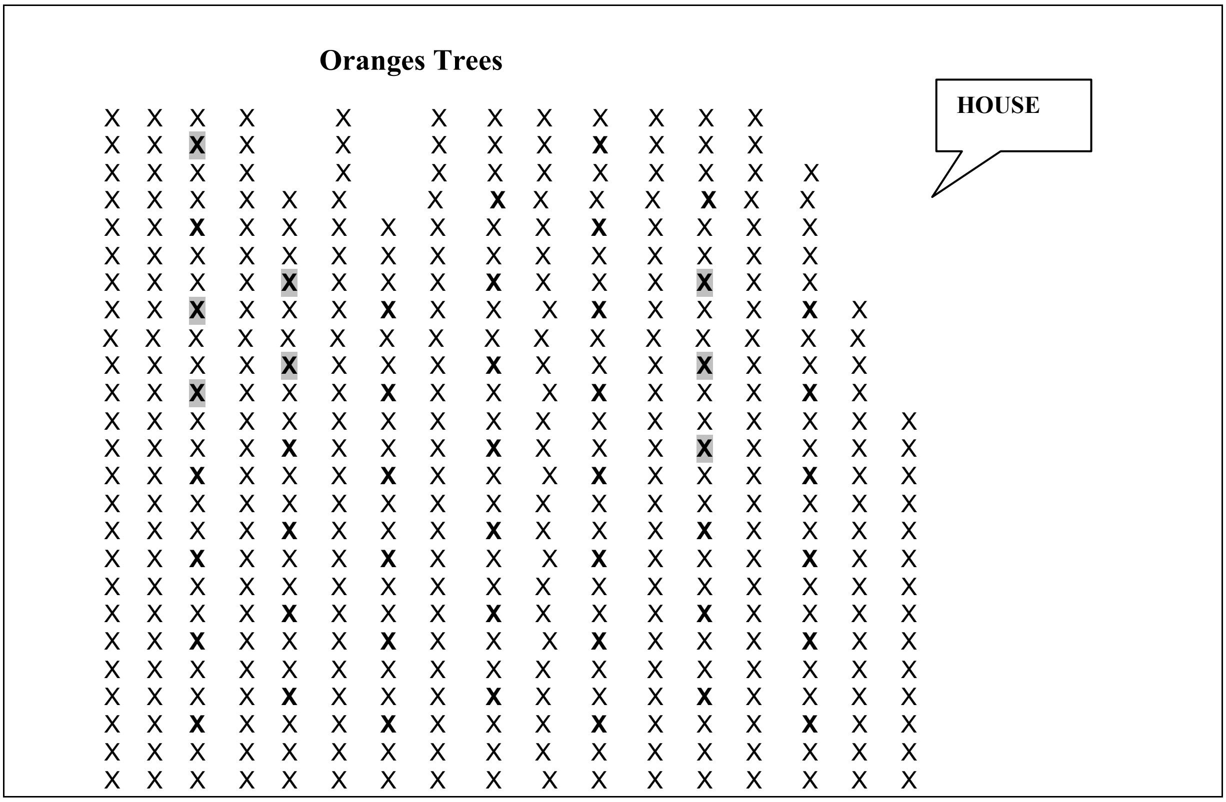


FIG. 2. Distribution of the orange trees (marked with X) and traps (bold X) and the sites where the largest number of medflies were captured (bold X with gray background) at La Guácima orchard, Alajuela. January - March, 2005.

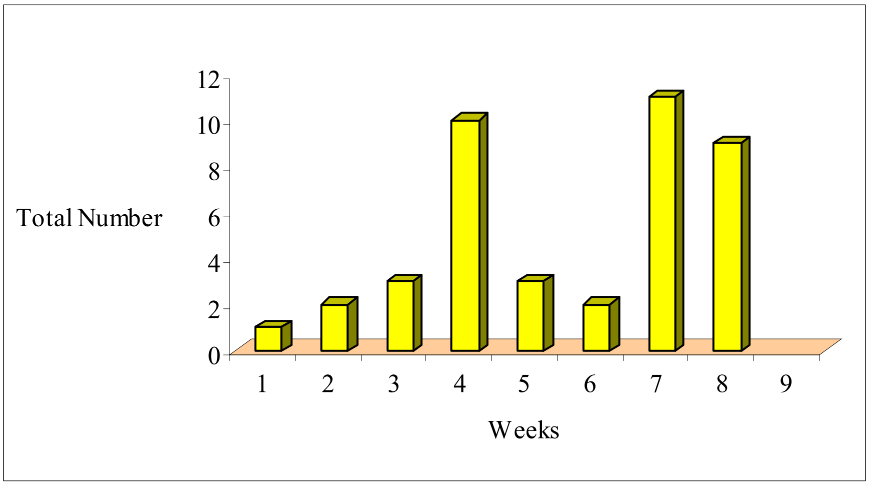


FIG. 3. Medflies captured per week at the La Guácima orchard during the application of bait stations,. January - March, 2005.

FIGS. 4 and 5 show the trend of the medfly population density with low levels at the start of the experiment (first two weeks) and with a sudden increase in the following weeks.

The low density of the population for *La Guácima orchard* that is shown in Table 1 and FIGS. 3 and 7 could be a result of the suppression effect of the bait stations. The increase in the population density in the 4th and 7th week may be related to the population increase that occurred in the nearby site of Vargas orchard (FIG. 5).

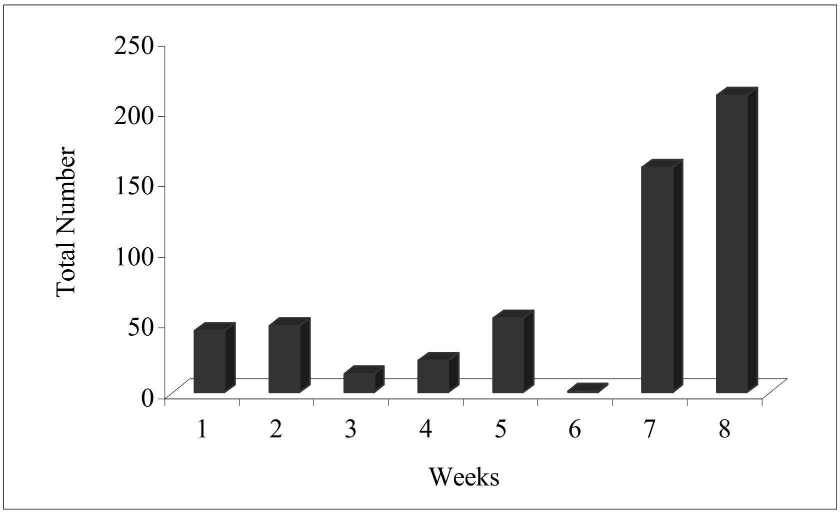


FIG. 4. Medflies capture per week at the Ruiz orchard. January - March, 2005.

The decrease in the number of adult flies collected at Ruiz orchard during weeks 3 to 6 could be related to the variation of the climatic factors in this period (very cold days, cloudy days, or strong winds), fallen traps, or anthropocentric factors as harvesting ripe fruits (FIG. 4).

TABLE I. FLIES FOR TRAP PER DAY AT LA GUACIMA ORCHARD WHERE BAIT STATIONS WERE USED AND AT RUIZ AND VARGAS ORCHARDS WERE NO BAIT STATIONS WERE USED. JANUARY - MARCH, 2005.

Week	Guacima	Ruiz	Vargas
1	0.04	7.33	WD
2	0.04	7.83	WD
3	0.06	2.16	10.5
4	0.2	3.83	20.5
5	0.06	8.83	10.25
6	0.04	0.16	8.5
7	0.22	26.6	20.25
8	0.18	35.16	8.5

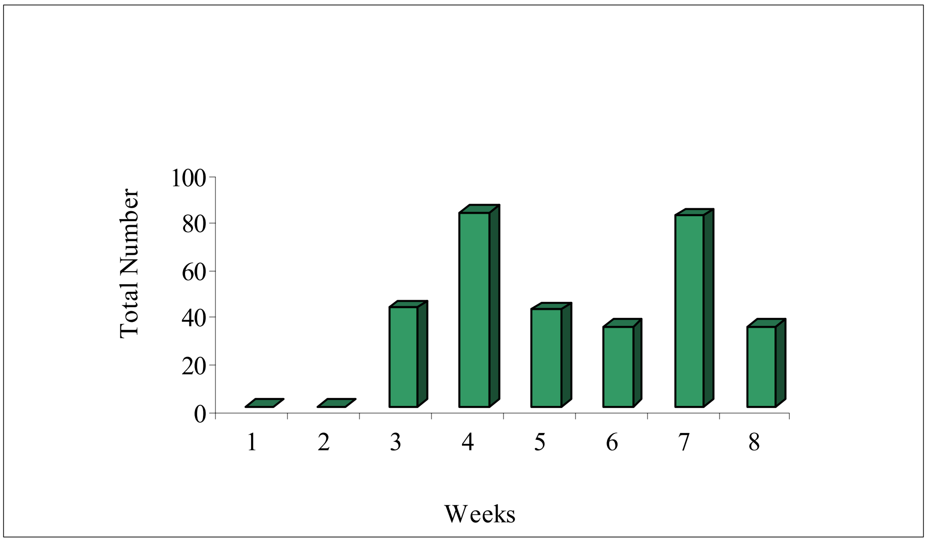
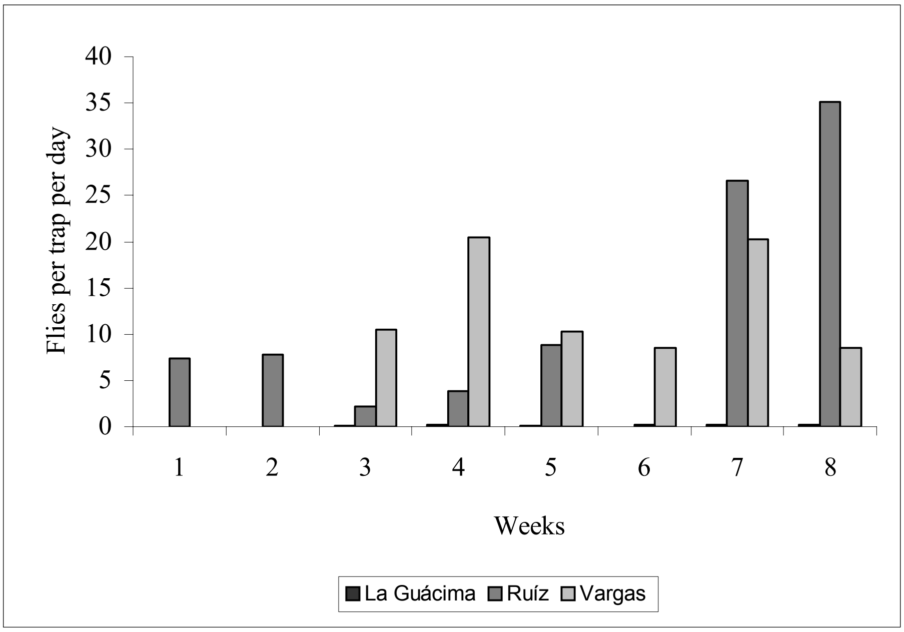


FIG. 5. Medflies captured per week at Vargas orchard. February - March, 2005.



FG. 6. Comparison of the number of flies per trap per day at La Guácima orchard, where bait stations were applied, and at Ruiz and Vargas orchards. January - March 2005.

The presence of mefly larvae was evaluated in ripe oranges at the Ruíz and La Guacima orchards. FIG 7 shows that in the eight analyzed samples, the percentage of infested fruits at Ruíz orchard was variable and relatively high, and at the La Guácima orchard it was 0%.

4. CONCLUSIONS

The difference in infestation levels (both adults in traps and infested fruit) between the La Guácima orchard and Ruiz and Vargas orchards during the study period, could be the suppression effect of the bait stations used for control in the La Guácima orchard.

The fruit fly population density increased as a result of more favourable climatic conditions and fruit maturation phenology of the crop during the months in which the experiment was carried out.

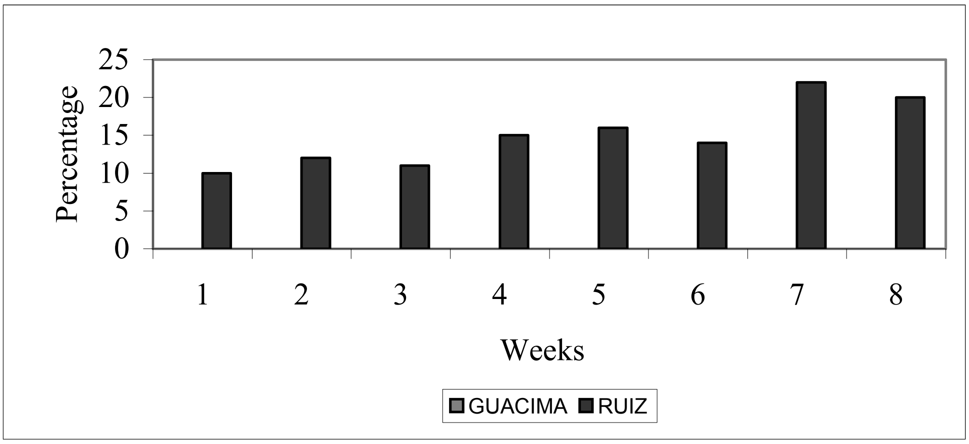


FIG. 7. Percentages of oranges infested with medflies at Ruíz and La Guácima orchards. January - March, 2005.

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EXPERIMENTS OF ATTRACTANTS FOR Anastrepha striata IN COSTA RICA

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Abstract

The experiments were carried out in several orchards that are hosts of *anastrepha striata* (diptera: tephritidae). The orchards are: (1) grecia canton (year 2001) which is a mix coffee and orange orchard, (2) esparza canton (2002 and 2003) which is a mango orchard, (3) pocora (2002 and 2004) which is a guava orchard, and 4) corralar (2002 and 2004) which is also a mixed coffee and orange orchard. The purpose was to determine the responses of the guava fruit fly *a. Striata* to seven attractants: (a) nulure, (b) ammonium acetate (aa) at a release rate of 150 µg nh_4/hour + putrescine (pt), (c) aa at 300 µg nh_4/hour + pt, d) aa at 600 µg nh_4/hour +pt, e) ammonium bicarbonate (ab) at 300 µg nh_4/hour + pt, f) aa at 300 µg nh_4/hour + pt + trimethylamine and g) torula yeast. Each experiment lasted eight weeks, with a change of the attractants every four weeks and biweekly collecting of the captured fruit flies and non-target insects. The data are expressed by means of flies per trap per day (ftd). In the experiment carried out in pocora (2004) and in corrralar (2002 and 2004) the highest ftd was obtained with nulure (0.92, 0.021 and 0.02, respectively). In esparza (2002) and pocora (2002) the largest ftd was obtained with torula (0.03 and 0.12, respectively) and the second best was nulure. In grecia (2001) and in esparza (2003) the best attractant was the mixture of ammonium acetate with putrescine. In grecia (2001), pocora (2004) and corralar (2002), the second best was torula yeast. Important information on the presence, abundance and fluctuation of *a. Striata* populations was obtained under diverse climatic conditions and crop phenology. This information serves as an important basis to continue studies on the effectiveness of trapping systems used against this fruit fly species and potential use of bait stations. .

1. INTRODUCTION

The studies of the responses of the tephritids to different attractants are of great importance to determine the compounds or mixtures of compounds to which different fruit fly species respond, early detect the fruit fly populations and attract the largest amount of individuals of each species and sex.

This information is also used to determine the best control strategies including bait stations and the release of sterile fruit flies.

Anastrepha striata Schiner (Diptera: Tephritidae) is a pest well distributed and that occurs at high population levels throughout Costa Rica [1, 2]. This fly has been collected in the dry region of the country (Guanacaste Province), in tropical humid regions in the Atlantic Zone (Limon Province) and in the Pacific region in places of high precipitation (Puntarenas Province and San Carlos Canton). As well as in intermediate elevation areas (Turrialba and Jiménez Cantons, in Alajuela and Heredia Provinces) and even in high elevation areas such as Monteverde (1,510 m.s.n.m.) [3].

In several of these regions, the fruit production is an important agricultural activity. In some cases there are extensive areas of citrus and mango, as well as mixed orchards of coffee and oranges, guava and coffee, guava and cattle, among others.

Anastrepha striata is known popularly in Costa Rica as the "guava fruit fly" because it primarily infests fruits of the Myrtaceae family in particular guava (*Psidium guajaba*), which is the most wide-spread in the country. Consumption of this fruit is frequent, and the pulp is used to prepare marmalades, juices, yogurt, and several other processed foods.

It also infests other common Myrtacea plants in Costa Rica such as the “cas” (*P. friedrichsthalianum*), as well as in another wild myrtacea called “guísaro” (*P. savanarum*) and in an introduced species called “Spanish guava” or “guava of the Peru” (*P. catlleianum*).

These hosts grow both cultivated and wild throughout almost the whole territory and they have several fruiting periods during the year. This is one of the reason why *A. striata* populations are present in high numbers throughout the entire year. It also infests fruits of more economic importance, such as the orange (*Citrus cinensi*: Rutaceae), mango (*Mangifera indica*, Anacardiaceae), avocado (*Persea Americana*, Lauraceae), "jocote" or "jobo" (*Spondias mombim*, Anacardiaceae), and "nance" (*Birsonima crassifolia*, Malphigiaceae). [1, 3, 4].

The purpose of this study is to present the results of the experiments carried out to determine the response of the guava fruit fly, *Anastrepha striata,* to Multilure traps baited with several attractants in different fruit orchards, weather and phenological conditions and at varying population levels.

2. MATERIAL AND METHODS

The experiments were carried out in different sites and fruit crops. Three were done in mixed coffee and citrus orchards including: The first one in Cooperative Victoria R L, in Grecia Canton and the other two in Corralar, Mora Canton in San José Province. The first one was a 30 ha orchard of coffee and orange. This experiment was carried out from June 11 to July 30, 2001. Those in Corralar were done at a 60 ha coffee and citrus orchard, property of the Beneficio Los Anonos Company, during the transition period of the rainy to dry season (November 4 to December, 23, 2002). This is the final period of the orange crop that bears fruit during the rainy season, and it coincides with the maturation and harvesting of the coffee and beginning of the orange crop that bears fruit during the summer. For this reason, fruit flies have a continuous availability of fruit hosts where they can build up their populations. The second experiment in this site was carried out during the rainy season between June 16 and August 12 of 2004, a time in which there was a small quantity of ripe oranges, but no mature coffee beans.

In Esparza, the experiments were carried out in a 80 ha mango orchard cultivated with the Tommy Atkins variety, located in San Juan Grande de Esparza, in Puntarenas Province. This property is located in an area of tropical dry forest in the transition area to mountain, and the experiment was done during March and April of the 2001, the end of the dry season and when the maturation of this fruit is starting. The second experiment was done between April 21 and June 12, 2003, during the transition from the dry to the rainy season.

The studies carried out at a guava orchard were done on a property of 30.0 Ha, of which 10.0 Ha are planted exclusively with guava, and which belongs to the Fruta Deliciosa Company. This orchard is located in the Pocora district, Guácimo Canton in Limón Province. These experiments were carried out from September 9 to October 31, 2002, from February 26 to April 22, 2004, and from September 2 to October 28, 2004.

The experiments lasted eight weeks. The attractants were changed once, after four weeks.

In each case 49 traps were placed with seven combinations of attractants (treatments), seven traps for each evaluated formulation (Table I). (A) NuLure, (B) Ammonium Acetate (AA) with a release rate of 150 μg NH4/hora + Putrescine (PT), B) AA to 300 μg NH4/hora + PT, (C) AA to 600 μg NH4/hora +PT, (D) Ammonium Bicarbonate (AB) to 300 μg NH4/hora + PT, (E) AA to 300 μg NH4/hora + PT + Trimethylamina and (F) Torula Yeast.

Each trap was placed at a distance that oscillated between 25 and 30 m between each tree, using a Latin Square experimental design in a uniform area of the orchard.

The attractants were placed inside MLT traps (plastic Mc Phail type) with a yellow color base and the upper part made of transparent plastic.

TABLE I. TREATMENTS, ATTRACTANT, LIBERATION RATE OF AMMONIUM AND CAPTURE MEANS OF THE INSECTS USED IN THE TRAPS.

Treatments	Attractants	NH_4 (ug/hora)	Retention
A	NuLure		Water
B	½ AA + Putrescine	150	270 ml.water + Triton
C	AA + Putrescine	300	270 ml water + Triton
D	2AA + Putrescine	600	270 ml.water + Triton
E	2 AB + Putrescine	300	270 ml.water + Triton
F	AA + Putrescine + Trimelthtilamine	300	270 ml.water + Triton
G	Torula		300 ml water

To standardize and to compare the information about the specimens collected in each trap, the data are expressed in flies per trap per day (FTD). This population index is calculated by dividing the total quantity of flies of the same species captured with each trapping system during the period of experiment by the number of traps, multiplied by the number of days that they were exposed in the field.

3. RESULTS

3.1. Experiment in a mixed coffee and citrus orchard: Grecia, 2001

In the experiment carried out in the Grecia Canton, 4,549 tephritids were captured. 84.4% were medflies and 712 (15.6%) flies of the *Anastrepha* genus, of which 49 (1.1%) were of *A. striata.*

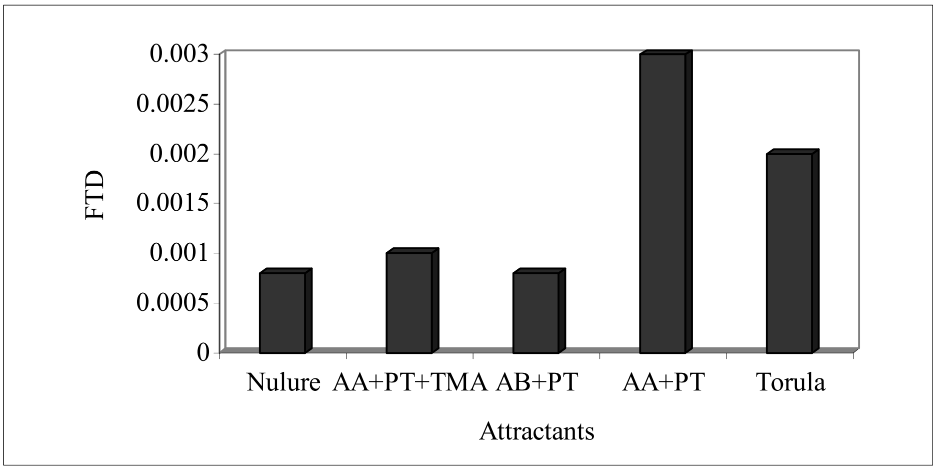

FIG. 1. Flies per trap per day Index for Anastrepha striata *captured in a mixed coffee and citrus orchard in Grecia, Costa Rica. June - July, 2001.*

This experiment was carried out in the rainy season during fructification of orange crop. The largest quantity of fruit flies of the species under study were attracted by the traps baited by the synthetic food lure Ammonium Acetate + Putrescine (300 ug/NH4), and in second instance by the natural attractant Torula Yeast (FIG.1).

In this case, the population of *A. striata* was the lowest of the species complex present in the orchard. Thus results show the response of the fruit fly to the attractants under low population levels.

3.2. Experiments in a mango orchard: Esparza, 2002 - 2003

In the study carried out in the mango orchard in 2002, 1,238 specimens were captured. Of them 569 (45.9%) were flies of the genus *Anastrepha* spp., of those 50 (4%) were *A. striata*. In the 2003 experiment, 792 tephritids were captured and only 15 (1.9%) were of *A.striata*.

The 2002 experiment carried out in Esparza was done during the dry season and in the period when the fruit began to ripen. In this case *A. striata* was also at low population levels in the orchard.

The results show a greater attraction of the Torula Yeast, followed by the NuLure that is also a natural product and by the mixture of AA + PT and TMA with a release rate of 300 ug/NH_4 (FIG. 2).

In the second experiment carried out in the same orchard during the transition period from the dry to the rainy season of 2003, the lelevls of this species were even lower. The results obtained showed an FTD slightly higher for the mixture of AA and PT with a release rate of NH_4 is of 300 ug/NH_4, followed by Torula and Nu Lure, both natural attractants and with equal results (FIG. 2).

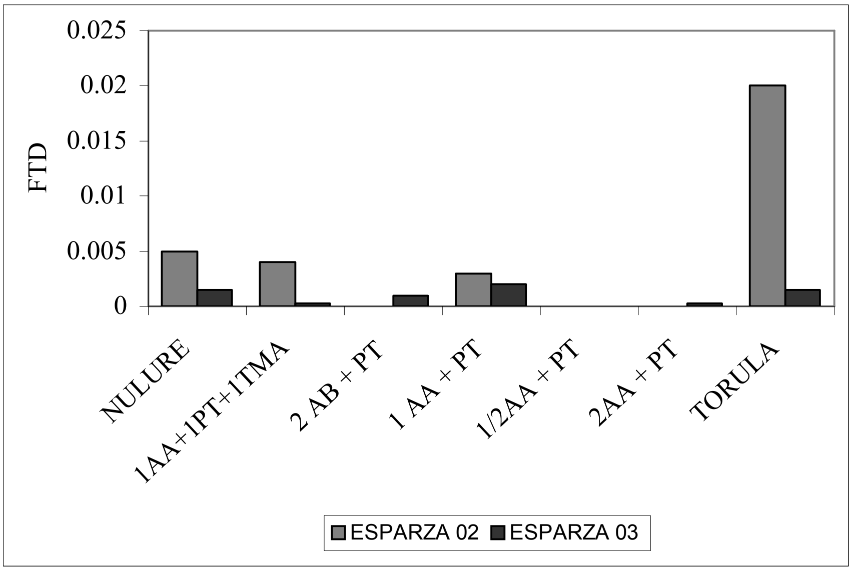

FIG. 2. Flies per trap per day of Anastrepha striata *captured in a mango orchard in Esparza, Costa Rica, 2002 - 2003.*

3.3. Experiments at a guava orchard: Pocora, 2002 and 2004

The studies carried out in this site were done to evaluate the response to the attractants in a guava monoculture, the most common hosts of this species in the country, under conditions of tropical humid climate and with high pest densities.

The quantity of tephritids collected during the eight weeks of the experiment of 2002 was 1,491 flies. Of them 1,477 (99%) are of the species under study. In the first experiment carried out in 2004, 9,251 specimens were captured in the same place, and of them 8,071 (87.2%) were of *A. striata*. In the second experiment of 2004, 2,037 tephritids were collected, and of them 1,786 belonged to *A. striata*.

In all the experiments carried out at the guava orchard, *A. striata* was the predominant species with very high capture percentages.

In the 2002 study, all the traps with the attractants evaluated captured *A. striata*. However, the natural attractants NuLure and Torula Yeast attracted a greater quantity: 468 were captured (FTD = 0.17) and 411 (FTD = 0.15) specimens, respectively. These were followed by the AA with PT with a release rate of 150 ug/NH4 (FTD = 0.06). The mixtures of AA w+ PT and TMA, AB + PT and the mixture of a dose of AA + PT, were the least effective ones (FIG. 3).

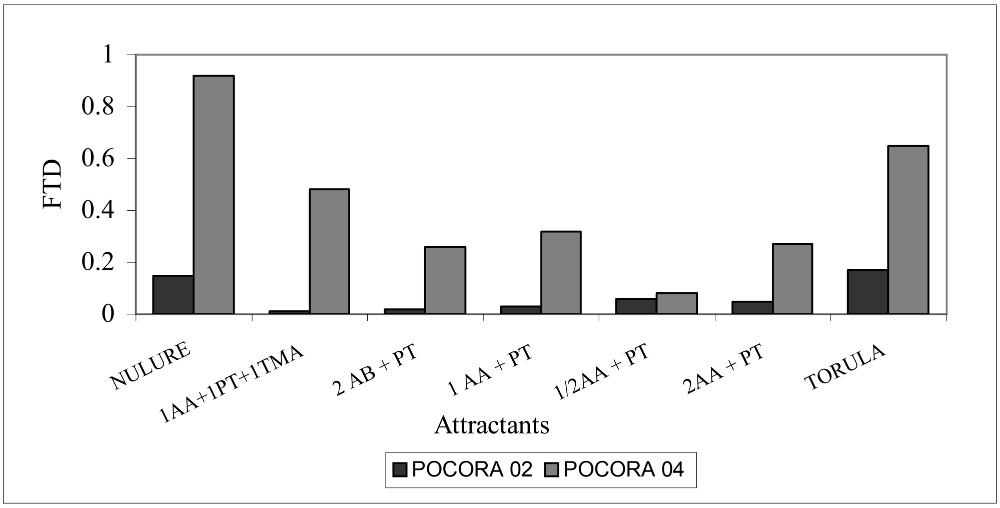

FIG. 3. Flies per trap per day for Anastrepha striata *captured in Pocora, Costa Rica, 2002 and 2004.*

Table II and FIGS. 3 and 4 show that under these conditions there was a preference for the natural food attractants over the synthetic ones.

The response of *A. striata* by sex for the two most effective attractants showed that in the 2002 experiments, 254 females (16.5% of the total captured individuals) and 214 males (13.9%) were catched by the Torula baited trap. The NuLure traps attracted 231 females (14.9%) and 180 males (11.7%). This information shows the similarity in the efficiency of the NuLure and Torula in luring both sexes using this attractant. Similar results were obtained with the Captures carried out with the AA + PT with a release rate of 150 ug/NH4 and AB + PT.

In the first experiment of 2004, 9,251 fruit flies were captured in the same orchard, and of them 8,071 (87.2%) belonged to *A. straita*, in this experiment a higher population level was observed. The best response was obtained with NuLure (FTD = 0.96) followed by Torula Yeast (FTD = 0.65), both natural attractants. From the synthetic attractants the best response was obtained with AA, PT and TMA with an FTD of 0.48 (FIG. 3).

The second 2004 experiment in Pocora was carried out during September – October. In this case 2,037 tephritid fruit flies were captured, and 1,786 were *A. striata*. The highest FTD was obtained by the MLT traps baited with NuLure (FTD = 0.29). This same attractant in Easy traps showed an FTD of 0.09. The MLT traps baited with ½AA+PT and with ½AA+½PT yielded a FTD of 0.1 and the formulation ½AB+PT an FTD of only 0.08.

3.4. Experiments in a mixed coffee and citrus orchard: Corralar, 2002 and 2004

In the study carried out in Corralar (2002), 3,853 tephritid fruit flies were captured, 114 (2.9%) were *A. striata*. In the 2004 experiment, 447 tephritids were captured, but only 5 (1.1%) were of the species under study.

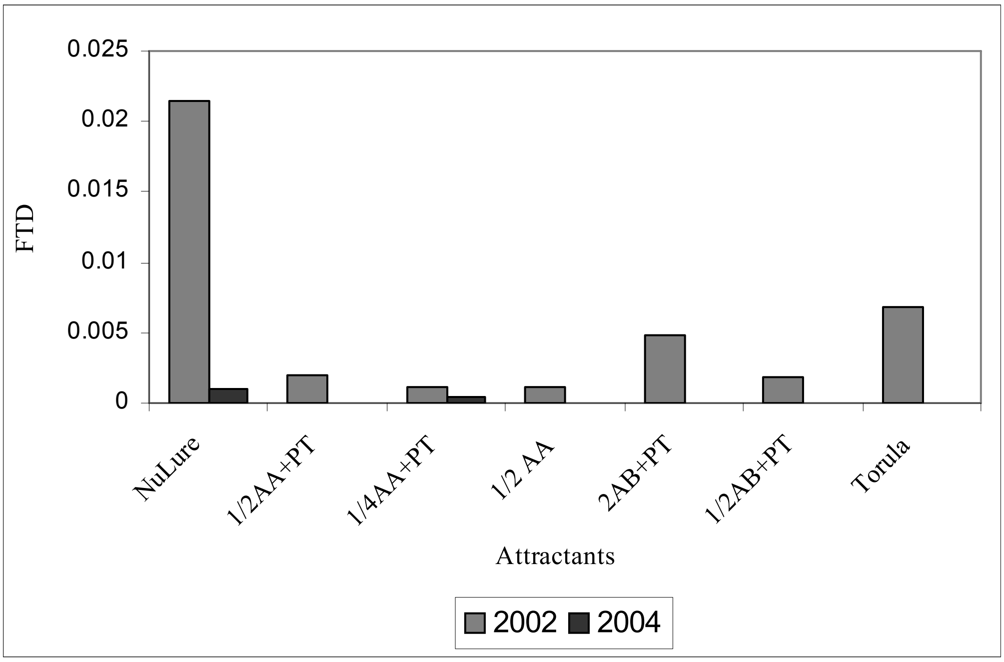

FIG. 4. Fly per trap per day Index for Anastrepha striata *captured in Corralar,* 2002 and 2004.

The study carried out in 2002 was done in the transition period from the rainy to the dry season, when there were mature fruits of the two hosts present (coffee and orange). The population under study were present at very low levels. The attractants that captured the largest quantity of fruit flies of the species studied were NuLure and Torula Yeast. The FTD obtained for NuLure was 0.02 and Torula Yeast 0.007.

The experiment carried out in the year 2004 was done during the rainy season when there were some ripe oranges but no mature coffee beans. The quantity of tephritids captured was 597, and of them only 6 (1%) were *A. striata*. Under these conditions the largest quantity of fruit flies was attracted by NuLure (FTD = 0.01) and in second place by the mixture of ¼AA + PT at a release rate of 75 ug/NH4 (FTD = 0.00036). In this experiment Torula Yeast was not included (FIG. 4).

Table II summarizes the results obtained, expressed in FTD values of the *A. striata* captured in the experiments.

TABLE II. FLIES PER TRAP PER DAY FOR *ANASTREPHA STRIATA* CAPTURED WITH DIVERSE ATTRACTANTS AND POPULATION LEVELS AT SEVERAL SITES IN COSTA RICA, 2001 - 2004.

Locality	Grecia	Esparza		Pocora			Corralar	
Year	2001	2002	2003	2002	2004(I)	2004(II)	2002	2004
(Captures)	(49)	(50)	(15)	(1,477)	(8,071	(1,786)	(114)	(5)
NuLure	0.0008	0.005	0.0015	0.15	0.92	0.29	0.0215	0.01
AA+PT+TMA	0.001	0.004	0.0003	0.01	0.48	NE	0.02	0
2AB+PT	0.0008	0.008[1]	0.001	0.02	0.26	NE	0.0012	0.0003
1AA+PT	0.003	0.003	0.002	0.03	0.32	NE	0.0011	0
½ AA+PT	NE	NE	0	0.06	0.08	0.11	0.0048	0
2AA+PT	NE	NE	0.0003	0.05	0.27	NE	0.0018	0
Torula Yeast	0.002	0.02	0.0015	0.17	0.65	NE	0.0068	NE

[1]Formulation with a single dose of ammonium bicarbonate.
NE= Not evaluated

The comparison of the data obtained shows in general that this species does not seem to have a strict preference for one of the evaluated attractants. It shows a better response to the natural attractants, both with low (Grecia, Esparza and Corralar) and high population density (Pocora) and in different environmental and phenological conditions of the fruit crop. Prefernce of this species for the tested attractants was not consistent.

In the experiment in Grecia, the highest FTD values was for the mixture of a dose of AA and PT, and the second was for Torula Yeast. In Esparza (2002) the largest quantity of fruit flies were captured in traps with Torula, followed by NuLure. In the study that was done in Esparza (2003), the highest FTD was obtained with the mixture of a dose of AA + PT (similar to the result obtained in Grecia), followed by Torula Yeast and NuLure with equal FTD's.

In the studies carried out under high population density (Pocora 2002 and 2004) the most effective attractants were NuLure and Torula Yeast. An equal result was obtained in Corralar in the experiment carried out in 2004 in which the highest FTD was obtained by the NuLure.

4. DISCUSSION

The increasing interest in the consumption of guava fruits and their derived products, the politics of conservation of the environment and biodiversity, the abuse of insecticides applied to control insect pests of agricultural importance, the incorporation of Costa Rica in free trade agreements with countries that are very demanding about the quality of foods that they import, and the interest in exporting fresh and healthy fruit and the products obtained from these to big consumer markets, demands that the stakeholders (agricultural authorities, producers and exporters) are aware of the economic damage that fruit flies inflict to the most important fruit crops in Costa Rica. Stakeholders should thus be proactive in supporting fruit fly research activities.

The information obtained through this research is basic to be able to design the best integrated pest management programme that is cost-effective in controlling *A. striata* but also enviroment friendly.

In the specific case of *A. striata*, it has special importance because there is a clear increase of guava consumption as fresh fruit and its by-products used to produce foods for children and adults, including marmalades, yogurt and beverages. The same way is true with the fruit known as "cas," originally used to prepare homemade drinks and that has now been industrialized. It is also recognized as a very important source of citric acid. These two Myrtaceas fruits are very widespread in the country, and area heavily attacked by tephritids in particular *A. striata*.

It should also be considered that *A. striata* is a species that infests other fruits of great economic importance such as sweet orange, mango and avocado [1, 2, 3].

Trading partners demand information about the pests of economic importance affecting agricultural products of interest. The information has to be technically sound and accurate. Thus, experiments with attractants that capture both females and males under low and high population levels and different environmental conditions are needed.

At the same time, the knowledge of the compounds that efficiently attract fruit flies will facilitate their use in bait stations for suppression of populations in and around the infested orchards using an area-wide approach. Selectivity in the attraction of a species towards a certain attractant is a necessary and very important requirement for the large-scale application of bait stations as negative impact of non-target insects is a major concern.

It is also important to take into account that the use of the Sterile Insect Technique (SIT) would greatly benefit if female biased attractants could be developed for the different fruit fly species of economic importance [5].

The phenology of the crop is an important factor in the attraction and captures of fruit flies. During the weeks of each experiment there were fruit trees in different phenological stages (flowering, with small immature fruit or ripe fruits) and this conditions introduced variations in the results.

5. CONCLUSIONS

The experiments carried out produced important, new and interesting information regarding the response of the guava fruit fly, *A. striata,* to different types of synthetic and natural food attractants.

The results showed that the strongest preferences of *A. striata* was for the attractants NuLure and Torula Yeast. These has the problem that these attractants are not specific and attract other non-target species which represents a problem for large-scale use.

The results obtained showed the effectiveness of these attractants to determine the presence of *A. striata* under low and high population levels and to assess the population fluctuation and spatial distribution.

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EXPERIMENTS OF DIFFERENT COMPOUNDS TO ATTRACT *Anastrepha obliqua* (DIPTERA:TEPHRITIDAE)

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Abstract

Information regarding eight experiments carried out between 2001 and 2004 to determine the responses of *Anastrepha obliqua* (Diptera:Tephritidae) to several attractants in fruit orchards in Costa Rica is presented. In a mixed coffee and citrus orchard where population levels where low in Corralar (2002 and 2004). In a guava orchard where population levels where low in 2002 and higher in 2004 in Pocora,. In a mango farm where population levels were high in Esparza (2001 and 2003). The Flies per trap per day index (FTD) obtained in mango in 2001 was 0.12 for Torula Yeast, for Ammonium Bicarbonate (AB) + Putrescine (PT) the FTD was 0.054 and for NuLure it was 0.053. In 2003 the highest attraction was obtained using NuLure (FTD = 0.025), AA+PT (FTD = 0.019), ½AA+PT (FTD = 0.013) and Torula Yeast (FTD = 0.0077). In guava (February to April of 2004) the highest FTD was obtained with NuLure(FTD = 0.11), with ½AA+PT (FTD = 0.07) and with Torula Yeast (FTD = 0.05). In the September – October, 2004, experiments the attraction was better using NuLure (FTD = 0.04), followed by ¼AA+AB+¼PT (FTD = 0.02) and by ½AA+PT and ½AA+¼PT both with a 0.01 FTD. In the mixed coffee and citrus orchard (November - December of 2002) the highest FTD was for the NuLure, Torula Yeast and ½AA+PT. The differences in the concentration of AA in the formulations of 1/2, 1 and 2AA+PT, did not yield sufficient data to be able to make a conclusion. With a single ½AA+PT, the FTD was 0.0008, with 1AA+PT it was zero, and with 2AA+PT it was 0.004. The formulation of 1AA+PT+TMA yielded an FTD of 0.004, and the same was obtained with 2AA+PT. In 2004, the largest number of *A. obliqua* was captured with NuLure (FTD = 0.0053). The Easy traps with the same attractant had a FTD of 0.001. In the formulations with AA, those with ½AA+PT captured the largest number of flies. The data obtained in all these experiments indicate that NuLure and Torula Yeast were better attractants to capture *A. obliqua* in Multilure traps. In most of them NuLure was better than Torula Yeast and the other compounds analyzed. The results are similar to what was found by some other scientists that evaluated the same trapping systems against the same fruit fly species. However, in some other cases the results are different as some scientists found a good response of *A. obliqua* to the synthetic food attractants. This is basically due to the different climatic conditions that prevail in the different countries where the experiments were conducted.

1. INTRODUCTION

Although in Costa Rica there are only 8,200 ha planted with mango trees (*Mangifera indic,* Anacardiaceae), this fruit is a very important product for the country. Last year 32,200 MT were exported to international markets such as the United States, Holland, Germany, the United Kingdom and Belgium, among others [1].

One of the most important problems in the production of this fruit is the damage that a number of species of Tephritid flies inflict.

Basic studies that have been carried out in Costa Rica about the Tephritid species, their hosts and phenology [2, 3, 4, 5, 7, 8]. These studies show that the flies causing major damage are several species of the genus *Anastrepha*, mainly *A. obliqua.* Soto-Malitiu and Jirón [9] and González [10] showed damage levels from this species oscillating between 20 and 80%. For these and many other reasons it is necessary to study their biology, the population dynamics, and their hosts in detail.

Those studies have been carried out by means of fruit sampling from a number of places [2, 5, 6] and trapping using only one attractant to capture tephritids, Hedstrom [5] and Elizondo [7].

The present investigation was carried out using Multilure traps baited with different attractants to determine their efficiency in attracting *A. obliqua*. The study was done in a mango orchard and in other fruit orchards where this fruit fly species is a secondary pest.

2. MATERIAL AND METHODS

The experiments were carried out in different fruit orchards and time periods. In a 80 ha mango orchard of the Tommy Atkins variety located in San Juan Norte de Esparza, Puntarenas (Site 1) during March and April, 2001 and between April and June, 2003. In a guava orchard (*Psidium guajav,* Myrtaceae) in Pocora, Guácimo Canton (Site 2), during September and October, 2002 (in the rainy season that included a three week period of reduced rain fall), between February and April and September to October of 2004. And at a mixed coffee and citrus orchard of 60 ha in Corralar de Mora, San José (Site 3), during November and December of 2002 and between June and August, 2004.

Each experiment lasted eight weeks. The insects captured in each trap were collected twice per week. Multilure traps, were used and treatments were distributed in the field following a Latin Square Pattern. Each trap was placed in the upper two thirds of the south-east border of the tree foliage, in a relatively open space to avoid leaves obstructing the entrance of the traps. The traps were separated by a 25 to 35m space between each other. The trees where the traps were placed have a similar size, density, and fruit maturation stage.

The attractants used varied from one experiments to another. The traps were baited with seven types of different attractants: 1) Solution to 9% of NuLure (NU), 3% Borax and 88% water (by weight), 2) Ammonium Acetate (AA) + Putrescine (PT) + Trimethylamine (TMA) and 300 ml of water with one or two drops of Triton or Propilengycol as a retention medium, 3) Several concentrations of AA and PT with Triton in water as a retention medium, 4. AA + Putrescine and 300 ml of water and surfactant, 6) Torula Yeast in 300 ml of water, 5) Ammonium Bicarbonate (AB) and PT with 100 ml of water and one or two Triton drops and in a single case, a yeast ferment attractant (optional attractant) called ACAVI. The results are expressed using fly per trap per day index (FTD) that is the total amount of flies captured with each attractant divided by the number of traps with each attractant multiplied by the number of days the traps were exposed in the field. Results were analyzed by means of an Analysis of Variance with the JMP Program.

3. RESULTS

3.1. Fruit fly captures

Table I shows the total amount of *A. obliqua* caught in the traps for the seven experiments carried out between 2001 and 2004.

Althougt *A. obliqua* is considered to be the main mango tephritid pest in the country, in the two experiments carried out in a mango orchard (Site 1) it was the species with the second highest population level, in both cases surpassed by the medfly (*Ceratitis capitata*, Wied.). During the experiments this species was captured in all the trap inspections done in the study periods.

3.2. Experiments with attractant

3.2.1 Site 1

FIG. 1 shows the results obtained during the experiments carried out in site 1 in 2001. It shows that the highest FTD values for males and females of *A. obliqua* was for the Torula Yeast (FTD = 0.076 for males and 0.047 for females), the AB + PT was the second best for males (FTD = 0.038) but not for females (FTD = 0.015). It is important to observe that the quantity of collected males was larger than that of females except for NuLure. There was no statistical difference between the treatments.

TABLE I. QUANTITY AND PERCENTAGE OF *A. OBLIQUA* COLLECTED IN THE EXPERIMENTS CARRIED OUT BETWEEN 2001 AND 2004.

Locality	Site 1		Site 2			Site 3	
Year	2001	2003	2002	I -2004	II -2004	2002	2004
Amount Percentage	491 (39.6)	216 (27.3)	3 (0.20)	933 (10.1)	251 (12.3)	20 (0.5)	25 (4.2)

The results of the experiments carried out in 2003 in the same orchard show that the NuLure was the best attractant with a larger quantity of specimens of *A. obliqua* captured (FTD = 0.005 for males and 0.02 for females). Then, in descending order are the attractants 1AA+PT (FTD for males = 0.003 and 0.016 for females) and ½AA+PT (FTD for males = 0.003 and for females = 0.010). The Torula Yeast was the best in the 2001 experiments and in 2004 it was the fourth (FTD for males = 0.0007 and for females 0.007) (FIG. 2). There were no significant statistical differences between the treatments.

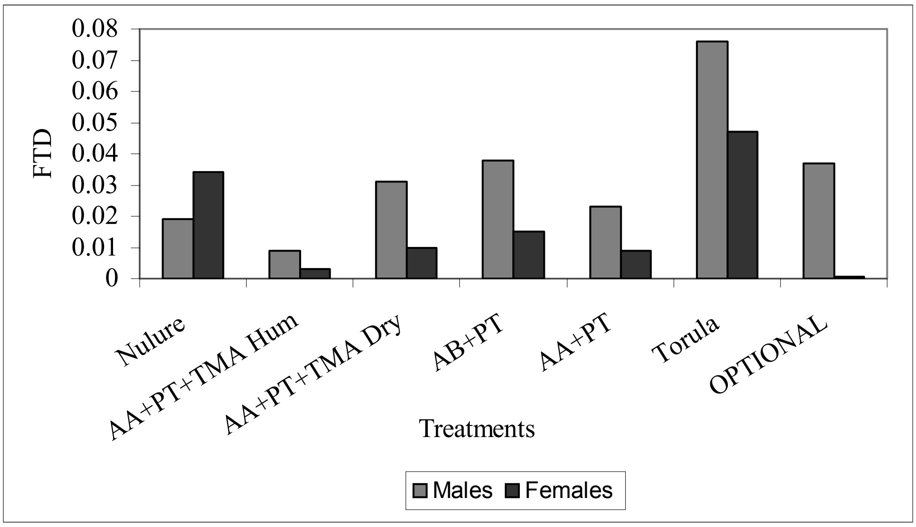

FIG. 1. Fly per trap per day of males and females of Anastrepha obliqua *collected at Site 1. March - May, 2001.*

The comparison of three doses of AA (1/2, 1 and 2) with PT showed that the dose of 1AA+PT was more effective than the one with ½AA+PT, and that this was better than the one composed of 2AA+PT. (FIG. 2). Better results were also obtained with the formulations of ½AA+PT and 1AA+PT than with those based on AB+PT (FIG. 2).

The comparison of the results obtained in 2001 with those of the 2003 experiments showed variations. In the first experiments the Torula Yeast, NuLure and the AB with PT formulation attracted a larger quantity of *A. obliqua*. But in the 2003 experiments, the best results were obtained with the NuLure and AA+PT formulation (FIGS. 1 and 2).

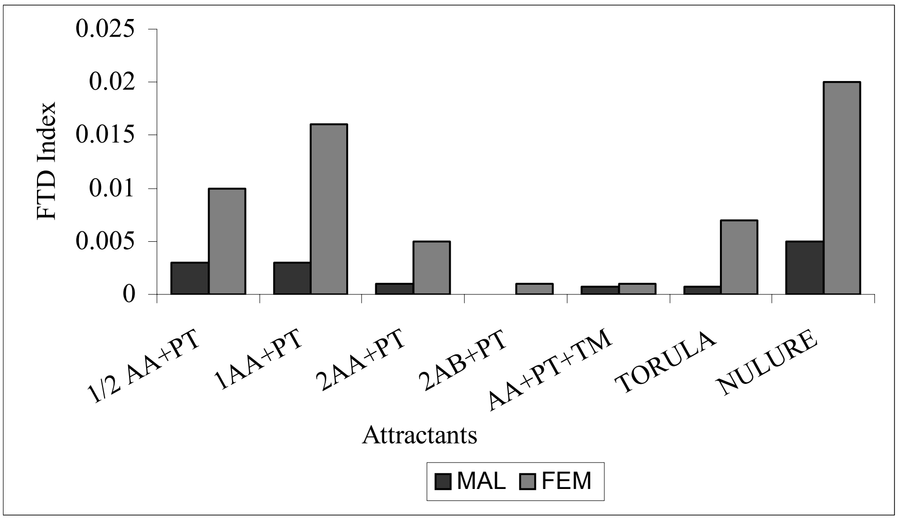

FIG. 2. Fly per trap per day for males and females of Anastrepha obliqua *captured at Site 1. April - June, 2003.*

3.2.2. Site 2

The guava (*P. guajava*: Anacardiacea) is a common and popular fruit in Costa Rica. It has a great latitudinal and altitudinal distribution and it is the host of several tephritid species [2].

In the experiments of attractants carried out in a guava plantation, *A. obliqua* represented the second most frequent species of those that were collected. The 2002 year was not analyzed since on that occasion only three specimens were captured: one female with ½AA+PT, one male with Torula Yeast and another with NuLure.

In the February – April, 2004, experiments (a period with low rain) and prior to the harvest time of the fruit, 933 *A. obliqua* were captured. FIG. 3 shows the FTD for males and females obtained in this experiments. The data obtained for *A. obliqua* females shows that the highest FTD was obtained with the natural attractant NuLure (FTD for males = 0.033 and for females 0.087), the second highest index was obtained with the synthetic food attractant ½AA+PT (FTD for males = 0.019 and 0.046 for females) and the third place was obtained with Torula Yeast (FTD for males = 0.012 and for females 0.039). The synthetic formulation ½AA+PT was more efficient than that of ¼ of AA+PT (FTD = 0.0074 for males and 0.021 for females) and this was better than that with ½AA (without PT) (FTD = 0.0055 for males and 0.021 for females). All the FTD indexes were higher for females than males. The results showed statistical differences between the responses of each sex to the attractants and between the NuLure and 2AB+PT treatment.

In the experiments carried out between September – October, 2004, during a period of low rain fall and prior to the harvest time of the fruit, other parameters were analyzed as is shown in the Table 2. *Anastrepha obliqua* was more attracted toward the Multilure traps baited with NuLure (FTD for males = 0.024 and 0.044 for females), then toward traps with ½AA+PT with water (FTD Index for males = 0.008 and 0.016 for females). The traps with ½AA+¼PT obtained a FTD of 0.003 for males and 0.0085 for females (FIG. 4).

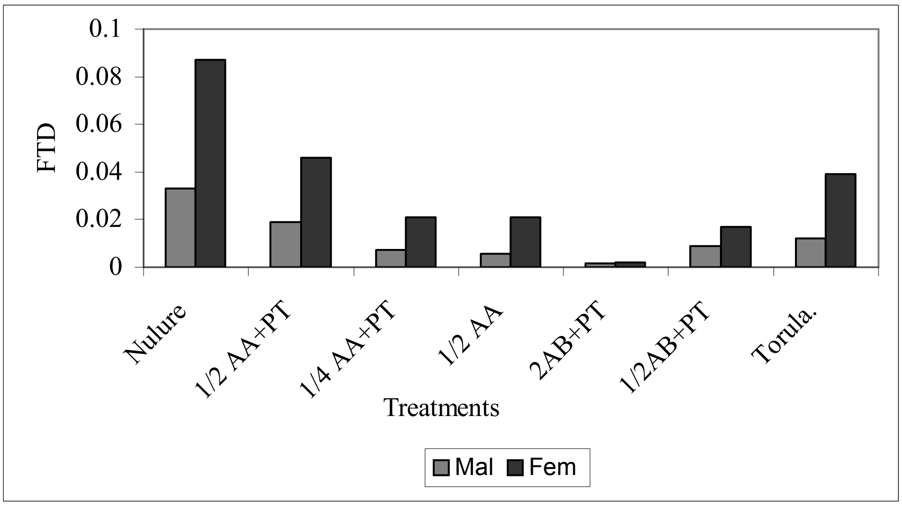

FIG. 3. Fly per trap per day index for males and females of Anastrepha obliqua *captured in Site 2. February - April, 2004.*

The capacity of Multilure and Easy traps baited with NuLure to catch fruit flies was compared. The information obtained shows that there are large differences between both traps since the attraction in Multilure traps was higher than in Easy traps (Table 2, FIG. 4).

TABLE II. FLIES PER TRAP PER DAY FOR MALES AND FEMALES OF *ANASTREPHA OBLIQUA* CAPTURED WITH TWO TYPES OF TRAPS, TWO RETENTION MEDIUMS AND VARIOUS ATTRACTANTS IN SITE 2. SEPTEMBER - OCTOBER, 2004.

Traps	Attractants	Retention	FTD Index Males - Females
Multilure	NuLure	Solution	0.024 – 0.044
Multilure	½AA+PT	H_20/Triton	0.008 – 0.016
Multilure	½AA+PT	Stiken	0.000 – 0.000
Multilure	½AA+¼PT	H_20/Triton	0.003 – 0.0085
Multilure	½AB+PT	H_20/Triton	0.005 – 0.0045
Multilure	¼AA+AB+¼PT	H_20/Triton	0.001 – 0.0035
Easy	NuLure	Solution	0.003 – 0.004

The effect of the retention mediums was also compared in Multilure traps baited with ½AA+PT. In those in which water and Triton were used a total FTD of 0.01 was obtained, and in those that used “sticky” inserts, no flies were captured. (Table II and FIG. 4).

The comparison of the FTD obtained between February and April with those of September - October, show that under the Pocora conditions the NuLure was the best attractant to capture *A. obliqua*, and that the ½AA+PT formulation and Torula Yeast were also efficient attractants.

3.2.3. Site 3

In the two experiments carried out at a mixed coffee and citrus plantation there were low *A. obliqua* population (Table I).

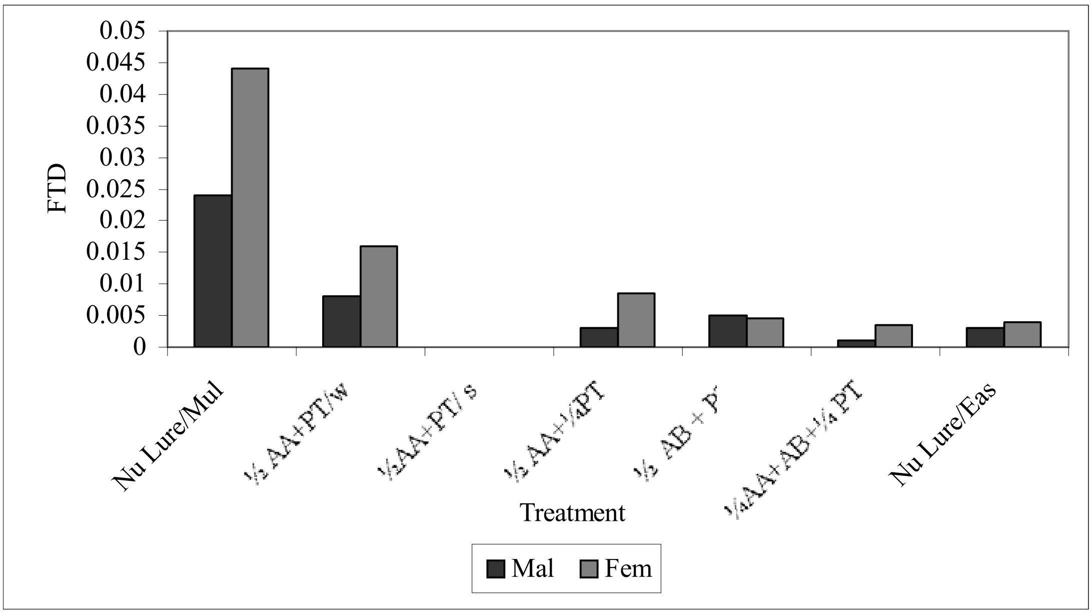

FIG. 4. Flies per trap per day for males and females of Anastrepha obliqua *captured at Site 2. September - October, 2004.*

The experiments carried out during November - December, 2002, were conducted at the end of the rainy season when mature coffee beans and ripe oranges were present. These are factors that favor the development of the tephritid populations.

In these experiments the highest FTD was obtained with the NuLure and Torula Yeast. The third most efficient was the ½AA+PT formulation (FIG. 5; Table 3). The data for the different AA concentrations (½, 1, and 2) + PT was not consistent. With single ½AA+PT a 0.0008 FTD was obtained, with 1AA+PT it was zero and with 2AA+PT it was 0.004 (Table 3; FIG. 5). The 1AA+PT+TMA formulation produced a 0.004 FTD, and this is equal to that which was obtained with 2AA+PT (FIG. 5). Most of the flies captured were females. There were not significant statistical differences between the treatments.

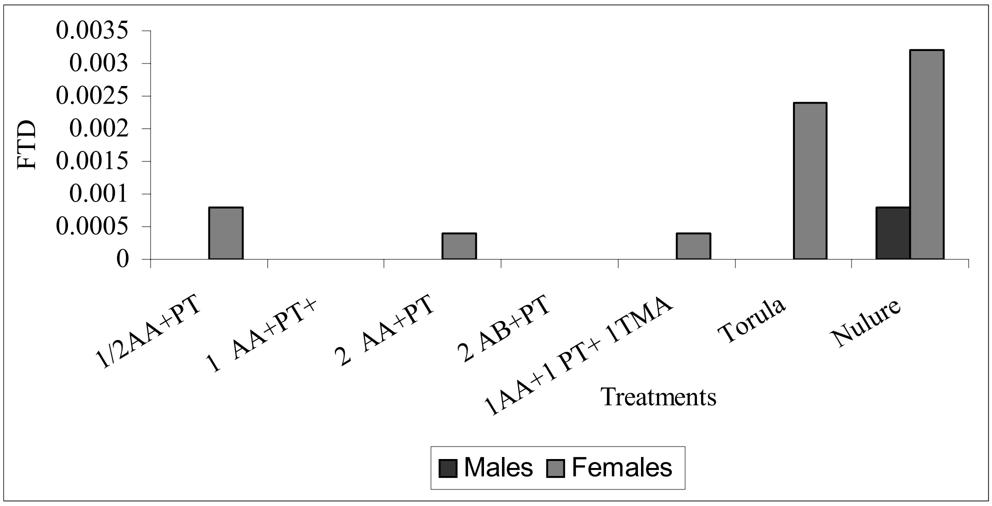

FIG. 5. Fly per trap per day index for males and females of Anastrepha obliqua *collected at Site 3. November - December, 2002.*

TABLE III. FLIES PER TRAP PER DAY OF *ANASTREPHA OBLIQUA* CAPTURED AT SITE 3. NOVEMBER - DECEMBER, 2002.

		Fly/Trap/Day Index		
Attractants	Retention	Males	Females	Total
1/2AA+PT	H_20/Triton	00	0.0008	0.0008
1AA+PT+	H_20/Triton	00	00	000
2AA+PT	H_20/Triton	00	0.0004	0.0004
2AB+PT	H_20/Triton	00	00	00
1AA+1 PT+ 1TMA	H_20/Triton	00	0.0004	0.0004
Torula Yeast	H_20	00	0.0024	0.0024
NuLure	Solution	0.0008	0.0032	0.004

The experiments carried out in the same plantation during 2004, were different from the first one in phenological aspects because it was done during the rainy period in which there were mature oranges but not ripe coffee beans.

In this occasion the quantity of *A. obliqua* captured was also small. The largest quantity was captured in Multilure traps baited with NuLure (FTD for males = 0.00071 and 0.0028 for females). The Easy traps with the same attractant obtained the same FTD for males and females (0.00035). In the AA formulations those with ¼AA+PT captured a larger quantity, only 3 specimens of this species. There were no significant statistical differences between the treatments (FIG. 6).

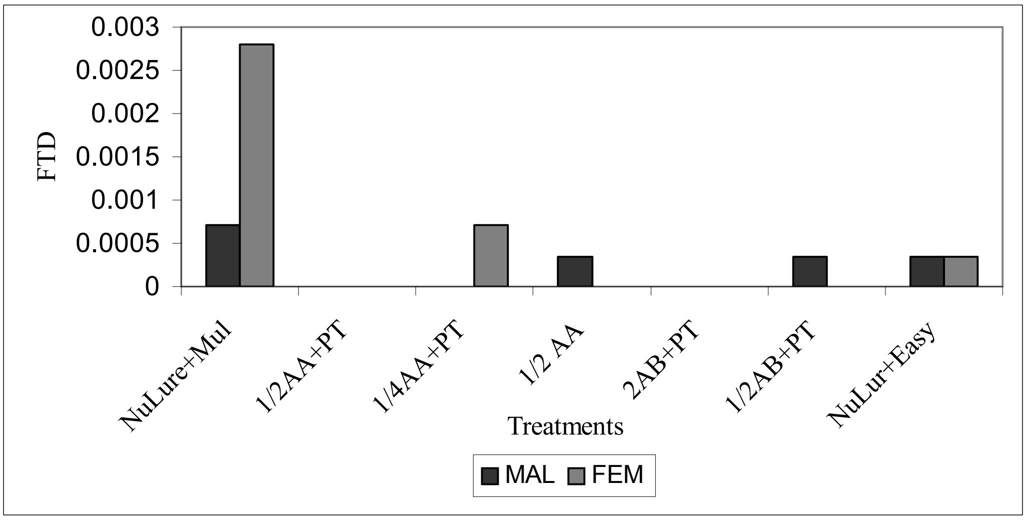

FIG. 6. Fly per trap per day index for males and females of Anastrepha obliqua *collected in Site 3. June - August, 2004.*

4. DISCUSSION

The study of attractants to capture insect pests of economic importance is an activity that has become more extensive and has acquired greater importance day by day [11].

The appropriate use of traps baited with specific attractants is necessary to early detect the presence of fruit fly species in certain areas. When it is a profitable business, this information is important to adopt necessary phitosanitary measures to control populations before they reach economic levels and in the case of fruit fly free areas to certify the absence of the pest. This has great value for the international market, for both importers and consumers.

The most important host of *A. obliqua* in Costa Rica is the mango. This is a fruit of great value in the national food industry because of its taste and nutritional properties and its acceptance in the world markets as North America, Europe and Japan is increasing. This pest also infests “jocote” (*Spondias purpurea*), “jobo” (*S. mombim*), yuplón (*S. dulcis*) and guava (*P.guajava*) [10].

The results obtained in the experiments carried out in Costa Rica are similar than those obtained by Canal *et al.* [12] in Colombia regarding the greater attraction capacity of the NuLure and Torula Yeast.

The response to these attractants has the limitation that it is not specific for *A. obliqua*, since other species of this and other groups are also strongly attracted to these same compounds [13, 14].

The results obtained in Costa Rica differ partially from those of other authors regarding the capacity of attraction of the AB+PT formulation because in our case, the response to these compounds were not very consistent.

Similarly, there are differences with the results obtained by Espinoza [15] since these researchers found the highest FTD with Torula Yeast and AB+PT and the lowest with NuLure.

In another study with these same species in Mexico, Gómez and Flores [16] ascertained the highest FTD values using AA+PT and AA+PT+TMA with propilenglycol as retention and with NuLure.

These differences in the results could be associated with the behavior of the multivoltines species such as *Anastrepha* spp., including dispersive movement and host sequence [17], and prevailing microclimates and phenology of the crop in different areas.

These studies demonstrate how important it is to understand the responses of fruit flies to different trapping systems given specific conditions of the crop and environmental conditions.

Developing cost-effective trapping systems is also relevant for extensive trapping programmes such as the one applied in Costa Rica and used to maintain the phytosanitary status of areas that produce fruit for exports to the United States [18].

5. CONCLUSIONS

The data obtained in all these experiments indicate that NuLure and Torula Yeast were better attractants to capture *A. obliqua* in Multilure traps. In most of them NuLure was better than Torula Yeast and the other compounds analyzed.

The results are similar to what was found by some other scientists that evaluated the same trapping systems against the same fruit fly species. However, in some other cases the results are different as some scientists found a good response of *A. obliqua* to the synthetic food attractants. This is basically due to the different climatic conditions that prevail in the different countries where the experiments were conducted.

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IMPROVED ATTRACTANT FOR FRUIT FLY MANAGEMENT PROGRAMMES

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Abstract

The Brazilian Agricultural Research Corporation (EMBRAPA) and its branch National Tropical Agroindustry Research Center (CNPAT) was involved in the Co-ordinated Research Project of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture from 2001 to 2005. The objective was to test new synthetic food attractants against fruit flies using Plastic McPhail type Multilure Traps (MLT). The food attractant NuLure captured the highest numbers of *Anastrepha* spp and *Ceratitis capitata* during four-year study. Fly Trap Day (FTD) indices, Relative Trap Efficiency (RTE %) and percentage of female per trap presented the highest numbers with the hydrolysate protein NuLure. The second best products to catch *Anastrepha* complex were the combination of the synthetic lures AA + PT (Ammonium Acetate + Putrescine). The combination AA+PT+ Trimethylamine (TMA) (Biolure) had in two years the worst performance to capture *Anastrepha* species but it was efficient to capture *C. capitata*. In the case of *Anastrepha spp*., it seems that separate components of the synthetic lure are more efficient than the whole three component lure to attract flies. All treatments captured a greater proportion of fruit fly females than males. The predominant species, over 80%, was *Anastrepha zenildae*. The peak of captures was concentrated during the dry season from January to June and the lowest captures was during the second semester, the rainy season, suggesting that population density is highly influenced by relative humidity and rain fall.

1. INTRODUCTION

This work is part of the Co-ordinated Research Project (CRP) of the Joint FAO/IAEA Division, which has long been involved in developing improved control and surveillance systems for integration into fruit fly SIT management programs.

The family Tephritidae comprises economically important fruit fly pests, which infest over 100 plant species from northern to southern Brazil. Some important species such *Anastrepha fraterculus* (Wiedemann, 1830), A. *obliqua* (Macquart, 1835), *A. grandis* (Macquart, 1846), *A. sorocula* (Zucchi) and the worldwide species *Ceratitis capitata* (Wiedemann, 1824) are highly destructive pests of tropical and temperate fruits [1, 2].

The most recent catalogue of *Anastrepha* listed 77 species [3]. In the last twenty years, 17 *Anastrepha* new species were found in Brazil. From the existing *Anastrepha* species in Brazil, hosts have been recognized only for 41 species. The genus *Anastrepha* is the most polyphagous in Brazil with 58 species of host plants. *Anastrepha* species in Brazil are associated with plants of 29 families. From a total of 41 *Anastrepha* species that are associated with different host plants, 37% of them feed on Mirtaceae and 24% on Sapotaceae.

Protein lures were attractive to *Anastrepha* species, especially the guava fruit fly, *A. striata* Schiner. The food attractant NuLure (hydrolyzed protein) in McPhail type Multilure traps (MLT) captured the highest numbers of *Anastrepha* spp. in guava orchards [4, 5]. In the 1950s, the use of hydrolyzed protein and partially hydrolyzed yeast in combination with organophosphate insecticides were used in Hawaii for the control of Oriental fruit fly, *Bactrocera dorsalis* (Hendel) [6].

The South American fruit fly, *Anastrepha fraterculus*, is the most studied fruit pest in Brazil, thus ample information regarding its biology and ecology is available. Adults are able to move 600 to 1000m from an area of native forest to the apple orchards. Plastic McPhail traps containing grape juice at 25% as attractant, was more effective in catching *A. fraterculus* than corn protein hydrolyzate, vinegar and sugar cane molasses [7, 8, 9].

The Mediterranean fruit fly, *Ceratitis capitata* (Wied.) (Diptera: Tephritidae) is one of the most serious fruit pests in the world infesting more than 300 plant species [10]. Several studies on population dynamic of *C. capitata* have been conducted in the tropics [11,12,13,14,15].

The Brazilian Agricultural Research Corporation (EMBRAPA) and its branch National Tropical Agroindustry Research Center (CNPAT) was part of the CRP of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture from 2001 to 2005. This paper reports the results of the CRP entitled "Development of improved attractants and their integration into fruit fly management programs". Its objective was to develop and to test new synthetic and natural fruit fly female biased attractants and to determine their efficacy compared to the common proteinaceous baits under different weather, host plants and fruit fly population levels.

2. MATERIALS AND METHODS

The trials were conducted in guava orchards at the municipality of Cascavel Limoeiro do Norte counties, State of Ceará. Seven treatments and 5 replicates were used with 2 observations per week during 8 weeks (Table I). Tests were conducted from 2001 to 2004. Plastic McPhail type Multilure traps (MLT) were installed in the experimental plot with uniform guava tress. Two rows of trees were left free on all sides of the plot. Traps were hung in the upper two thirds of the southeastern part of the host tree canopy. Traps were installed in a relatively open space with no leafs touching the trap. All traps were installed equidistant with 28 meters between traps. In the same block, trees with traps had similar canopy size, density and fruiting condition. Traps within a block were rotated sequentially after each weekly sampling. Each week the liquid with its ingredient was replaced. For the 8 week standard protocol, Ammonium Acetate (AA) and Putrescine (PT) were replaced by new attractants in the fourth week. Guava orchards were free from any insecticide application before and during the tests. The preparation of each trap followed the standard research protocol of the Joint FAO/IAEA Division.

Data were analyzed by site and by host type. Fruit fly captured were reported as mean number of males, females and total flies per trap per day; relative trap efficiency (i.e., percentage) of males, females and total flies captured among treatments, and as percentage of females in the total number of flies captured in each trap. Prior to the analysis of variance capture data was transformed to $\log_{10}(x+1)$ and percentage data to $\sqrt{x + 0.5}$. Statistical analyses were performed with analysis of variance (ANOVA) and pair wise comparison of means (Tukey's test, 95% confidence).

Guava (local variety) orchards were selected for the trials from 2001 to 2004. These orchards are located at the fruit production areas of the State of Ceará Brazil (Latitude 5°11' S, Longitude 39 16' O). The trials were conducted in two different periods from March to May and September to November of 2001-2004.

The climate in these counties is a semi-arid tropical with an annual average, minimum and maximum temperatures of 24.5-26°C, 22.3-23.6°C and 33.8-35.3°C, respectively. Relative humidity on average ranged from 79.0 to 86.5% and maximum of 89.7. Most rains occur from January to June with a historical average that ranges from 760 to 900mm per year. Winds are predominantly from north-northeast with a 90% of frequency and they are more intense from July to December with a maximum speed of 9.8.6 km/h.

TABLE I. ATTRACTANTS AND RETENTION MEDIUMS USED IN THE EXPERIMENTS.

Year	Treatments	Retention
2001/2002	NULURE	H_2O
	AA+PT+TMA	H_2O+TRITON
	AA+PT+TMA	PG
	AB+PT	H_2O+TRITON
	AA+PT	H_2O+TRITON
	TORULA	H_2O
	HYDROLIZED PROTEIN	H_2O
2002/2003	NULURE	H_2O
	1/2AA+PT	H_2O+TRITON
	AA+PT	H_2O+TRITON
	2AA+PT	H_2O+TRITON
	2AB+PT	H_2O+TRITON
	AA+PT+TMA	H_2O+TRITON
	TORULA	H_2O
2003/2004	NULURE	H_2O
	1/2AA+PT	H_2O+TRITON
	1/2AA+PT	STICK INSERT
	1/2AA+1/4PT	H_2O+TRITON
	1/2AB+PT	H_2O+TRITON
	1/4AA+AB+1/4PT	H_2O+TRITON
	1/4AB+PT	H_2O+TRITON

These orchards have been used for production of guava for fruit processing and local marketing. Each plot had a total area of 6 hectares. The space between plants and rows was 7m by 7m with a population of 204 plants per hectare. Pesticides were not used in these fields during the working period. Three rows and four plants in all sides were left free, according to research protocol. Drip irrigation is used in the orchards. Several small orchards and villages surround the working plots. The most common hosts were mango (*Mangifera indica*), *Citrus* spp, banana (*Musa spp*), *Spondia* spp, star fruits (*Averrhoa carambola* L.), cassava (*Manihot esculenta*) papaya (*Carica papaya*), melon (*Cucumis melo*), guava (*Psidium guava*) and a shade tree called tropical almond (*Terminalia catappa*). Most houses of the villages were spread out, and the closest fruit fly host trees were from 300 to 500m from the research plots.

3. RESULTS AND DISCUSSION

The food attractant NuLure captured the highest numbers of *Anastrepha* during the three year study (Tables II, IV, and VII). Fly Trap Day (FTD) index, Relative Trap Efficiency (RTE %) and percentage of female per trap were also the highest figures with the product NuLure (Tables III, and VI). The second best products to catch *Anastrepha* complex were the combination of the synthetic lures AA+PT, during the 2001/2002 and 2002/2003 experiments. However, during 2003/2004 experiments, the combination 1/4AB+PT captured more flies than 1/2AA+PT but there was no statistical difference. The combination AA+PT+TMA (Biolure) in two years had the worst performance in the capture of *Anastrepha* species but captured high numbers of *C. capitata*. It seems that for the *Anastrepha* species separate components of the synthetic lure are more efficient than the three components together (Biolure). Other parameters analyzed such FTD and RTE had similar response for the same combinations commented above. All treatments captured more females than males. The predominant species, over 80%, was *Anastrepha zenildae*.

TABLE II. MEAN NUMBERS OF MALE AND FEMALE FRUIT FLIES CAPTURED PER TREATMENT IN GUAVA ORCHARD IN THE STATE OF CEARÁ BRAZIL. 2002.

Treatment	*Anastrepha* spp			Ceratitis capitata			Total
	Male	Female	Total	Male	Female	Total	
NuLure	134.9 a	149.0 a	284.0 a	24.8 a	24.1 ab	48.9 a	332.9 a
AA+PT+TMA	32.9 d	53.2 c	86.1 c	18.8 ab	26.2 a	45.0 a	131.1cd
AA+PT+TMA+PG	65.1 bcd	99.3 b	164.4 bc	18.1 ab	26.4 a	44.5 a	209.0 c
AB+PT	46.6 cd	54.6 c	101.3 c	6.6 b	11.5 b	18.1 b	119.4 d
AA+PT	80.6 abc	103.5 b	184.1 b	17.4 ab	23.9 ab	41.3 ab	225.4 b
Torula	89.0 b	99.4 b	188.5 b	13.3 ab	16.5 ab	29.9 ab	218.2 bc
Hydrolyzed Protein	57.2 bcd	76.7 bc	133.9 cb	14.4 ab	18.1 ab	32.6 ab	166.6 bcd

Mean values within a column followed by similar letters are not significantly different (P≤0.05)

TABLE III. FLY PER TRAP PER DAY, RELATIVE TRAP EFFICIENCY AND % FEMALE PER TRAP FOR *C. CAPITATA* AND *ANASTRAPHA*S SPP ADULTS CAPTURED IN 2001 IN GUAVA ORCHARDS IN THE STATE OF CEARÁ BRAZIL. 2002.

Treatment	Avg. Flies Trap per Day (FTD)		Relative Trap Efficiency (RTE)		% Females per Trap	
	# Total		% Total		# Fem./ # Tot.	
	Cerat.	*Anast.*	*Cerat.*	*Anast.*	*Cerat.*	*Anast.*
NULURE	6.99	40.57	19.20	24.90	9.87	10.50
AA+PT+TMA	6.43	12.30	17.66	7.55	11.63	12.37
AA+PT+TMA	6.36	23.46	17.48	14.40	11.87	12.16
AB+PT	2.59	14.47	7.11	8.88	12.66	10.79
AA+PT	5.90	26.31	16.19	16.15	11.57	11.25
TORULA	4.25	26.68	11.67	16.38	11.08	10.45
Hydrol. Protein	3.89	19.14	10.69	11.75	13.34	11.46

TABLE IV. FLY PER TRAP PER DAY AND RELATIVE TRAP EFFICIENCY FOR MALE AND FEMALES *ANASTREPHA* SPP CAPTURED IN GUAVA ORCHARDS IN THE STATE OF CEARÁ BRAZIL 2003.

Treatment	Avg. Fly trap day (FTD)			Rel. Trap Efficiency (%)			%Fem per tra
	Male	Female	Total	Male	Female	Male	
NULURE	3.21	4.02	7.23	32.50	28.86	30.36	55.21
1/2AA+PT	1.36	2.05	3.41	13.76	14.72	14.32	59.81
AA+PT	1.23	1.81	3.04	12.44	12.99	12.77	57.90
2AA+PT	1.49	2.00	3.49	15.08	14.36	14.66	56.84
2AB+PT	0.35	0.64	0.99	3.54	4.59	4.16	61.81
AA+PT+TMA	0.37	0.74	1.11	3.74	5.31	4.66	67.05
TORULA	1.87	2.67	4.54	18.94	19.17	19.07	58.40
Total	9.88	13.93	23.81	100.00	100.00	100.00	

The numbers of males and females of *A. fraterculus* captured with NuLure were significantly superior compared to the other food attractants. Traps with the treatment AB+PT captured significantly lower numbers of adult males and females of *C. capitata* during the experiment in 2002, compared to the other food attractants. Therefore, only the treatment AB+PT was statistically different compared to others (Table I). There was no statistical difference among other treatments. The population of *C. capitata* in the years 2002/2003 and 2003/2004 was very low and therefore data was not analyzed. This low population was a result of the lack of rain during the second semester of those two years. The peak of capture concentrated during the dry season, from January to June, and the lowest captures were during the second semester in the rainy season suggesting that population density is highly influenced by relative humidity and rain fall.

TABLE V. MEAN NUMBER OF MALE AND FEMALES OF A*NASTREPHA* SPP ADULTS CAPTURED IN GUAVA ORCHARDS IN THE STATE OF CEARÁ BRAZIL. 2003.

Treatment	*Anastrepha* spp		Total
	Male	Female	
A – 1/2AA+PT+H_20+Triton	47.7c	75.5bc	119.5bc
B - AA+PT+H_20+Triton	43.1c	63.2c	106.4c
C - 2AA+PT+H_20+Triton	52.2bc	70.0bc	122.2b
D - 2AB+PT+H_20+Triton	12.4d	22.4d	34.7d
E - AA+PT+TMA+H_20+Triton	13.1d	25.9d	39.0d
F- Torula + H_20	65.4b	93.7b	159.1b
G - Nurule + Borax + H_20	112.4a	140.9a	253.2a

Mean values within a column followed by similar letters are not significantly different ($P \leq 0.05$)

TABLE VI. FLY PER TRAP PER DAY (FTD), RELATIVE TRAP EFFICIENCY AND % FEMALE PER TRAP FOR *ANASTRAPHA* ADULTS CAPTURED IN MLT BAITED WITH FOOD ATTRACTANTS FROM SEPTEMBER TO NOVEMBER 2004 IN GUAVA ORCHARDS IN CASCAVEL CE BRAZIL. 2004.

Treatment		Flies Trap per Day (FTD)			Relative Trap´Efficiency (%)			
		Male	Female	Total	Male	Female	Total	Female/ trap
A	NULURE	0.50	1.84	2.34	23.81	31.66	29.58	81.842
B	1/2AA + PT	0.19	0.53	0.72	9.05	9.12	9.10	86.260
C	1/2AA+PT	0.16	0.48	0.64	7.62	8.26	8.09	80.070
D	1/2AA+1/4PT	0.14	0.57	0.71	6.67	9.81	8.98	79.620
E	1/2AB+PT	0.25	0.70	0.95	11.96	12.05	12.02	70.044
F	1/4AA+AB +1/4PT	0.41	0.56	0.97	19.52	9.64	12.26	66.667
G	1/4AB+PT	0.45	1.13	1.58	21.43	19.45	19.97	82.394
	Total	2.10	5.81	7.911	100.00	100.00	100.00	

TABLE VII. MEAN NUMBERS OF ANASTREPHA ADULTS CAPTURED ON TUESDAY AND FRIDAY, RELATIVE EFFICIENCY OF TRAPS FOR FEMALE AND TOTAL OF CAPTURE IN MLT FROM GUAVA ORCHARDS IN CASCAVEL – CE BRAZIL. 2004.

Treatment	Trap Service Tuesday	Trap Service Friday	Relative Efficiency Female/Male	Total
NULURE	10.95	4.07a	3.83a	7.51a
1/2AA + PT	2.77bc	1.25bc	2.01ab	2.01bc
1/2AA+PT	2.00bc	1.60abc	2.29ab	1.80bc
1/2AA+1/4PT	2.72bc	2.30abc	2.18ab	2.51b
1/2AB+PT	3.17bc	3.65ab	2.19ab	3.41b
1/4AA+AB+1/4PT	0.42c	0.27c	0.83b	0.35c
1/4AB+PT	3.97b	3.15ab	3.42a	3.56b

Mean values within a column followed by similar letters are not significantly different (P≤0.05)

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BAIT MATRIX FOR NOVEL TOXICANTS FOR USE IN CONTROL OF FRUIT FLIES (DIPTERA: TEPHRITIDAE)*

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Abstract

The notion of geographical isolation as a protective barrier for a nation's agricultural assets is going fast by the wayside as agricultural trade expands globally. Barriers are breaking down in the interests of export or import of agricultural products and with expanded trade the probabilities of moving undesirable pests from one locality to another are increasing. The notion of invading pest species may be, in great part, the movement of people that facilitate the movement of exotic insects. The dilemma to a receiving state or country is what to do to do prevent the entry of, detect, or eliminate a new pest species. If the pest can not be eliminated, then, what is the risk and cost of living with it and manage its numbers. The first line of defence should be regulatory based on evidence provided by science. The second should be an active response that curtails the survival of the new pest. An insecticidal spray strategy has worked well time and time again against the Mediterranean fruit fly (*Ceratitis capitata)* and the oriental fruit fly (*Bactrocera dorsalis*) each time these fruit flies have invaded California in the past. The insecticide strategy is still being used against *B. dorsalis* but is being replaced against *C. capita* with continual releases of sterile flies. The action embodies the concept that the continued presence of sterile flies will nullify the reproductive capability of incoming feral flies due to shear competition for mates. The continual release of sterile flies appears to work very well in the Los Angeles basin area and targets only the species in question. However, such a technique is not available for a number of fruit fly species. Consequently, reliance on an insecticidal strategy will continue. But, if novel toxins with little or no contact toxicity are used, more attention must be given to the carriers of such toxins to ensure that they attract flies to spray deposits and entice them to consume the residues.

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EVALUATION OF CHEMICALS FOR THE DEVELOPMENT OF FEMALE ATTRACTING TRAPPING SYSTEMS FOR PEACH FRUIT FLY, Bactrocera zonata (SAUNDERS)

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Abstract

Experiments were conducted to evaluate various chemicals for the development of female peach fruit fly targeted trapping systems. Results indicated that the percentage of female catches was comparatively higher in the traps baited with Ammonium Acetate (AA) + Puterscine (PT) and in NuLure (hydrolysate protein) + Di-ammonium Phosphate using a 3:7 ratio than the other food baits. None of the chemicals captured male flies up to the level of Methyl Eugenol, which was almost 10 times higher than the other baits. It was observed that 300 ml water and 2 drops of Triton proved very effective for retention and catching of the fruit flies. Based on these findings it is apparent that synthetic food attractants provide an effective system for capturing the peach fruit fly. Field management studies revealed that based on adult catches in traps and fruit infestation, male annihilation technique (MAT) in conjunction with bait sprays (BAT) and cultural practices proved significantly more effective for the control of peach fruit fly in guava and mango orchards as compared to MAT + BAT without cultural practices and BAT + cultural practices.

1. INTRODUCTION

The major constraint in the production of fruits is the attack of fruit flies affecting both quality and quantity of the fruits in tropical, sub-tropical and temperate regions [1, 2]. A number of species are known to attack a wide range of high value fruits and vegetables but Tephritid fruit flies rank high among the pests. Fruits may be treated in various ways to kill the immature stages and there by minimize the risk that the pests will spread via marketing channels. However, the treatments are costly and may affect the quality of the products. Also, restrictions or bans on certain chemical treatments have made the certification of commodities for export difficult. Therefore, there is worldwide requirement for acceptable suppression measures capable of maintaining populations at very low levels and ultimately employed for fruit fly eradication programmes. In the case of most of the *Bactrocera* species female-targeted trapping systems are used as complementary trapping, because female lures are not as specific or attractive as male lures [3]. Female biased trapping systems are normally based on a McPhail type trap baited with a liquid hydrolysate protein and Torula yeast [4]. An effective female biased dry synthetic food attractant was developed for the Mediterranean fruit fly (*Ceratitis capitata*) [5,6]. Now the attractant is available as a two or three- component lure consisting of Ammonium Acetate (AA) + Trimethylamine (TMA), and AA+ Puterscine (PT) + TMA [4]. Methyl Eugenol (ME) is a strong male attractant of *B. dorsalis* and the peach fruit fly *B. zonata.* It is being used for male annihilation of both the species [7, 8, 9]. The development of female fruit fly targeted trapping systems, has opened a new venue and enhanced the efficiency of integrated pest management programme in recent years [10]. The system would lead to more effective population suppression and provide a better monitoring tool by attracting males and females in area-wide management of fruit flies. Considering the importance of female biased attractants a coordinated research project was started to develop a female biased trapping system for *B. zonata*.

2. MATERIALS AND METHODS

2.1. Evaluation of Ammonium Acetate, Putrescine and Trimethylamine to attract *B. zonata* females

Various attractants were tested in Plastic Multilure Traps (PMT) in a randomized complete block design using three replicates per treatment. The experiment was conducted at Delhi Farm on an area of 20 hectares. The experimental site was divided in three blocks and each block was used as a replicate. All the baits were received from the IAEA with a complete research protocol. No spray of any insecticide was done in the orchard during experimental period. The traps were hung horizontally in the upper two thirds of the south - eastern part of the guava tree at a uniform distance (30-35 meters apart from each other) at the height of about 2.5 m above the ground level on the trees. Trap catches were recorded twice a week (3 to 4 days interval) and the traps within the blocks were rotated sequentially after each reading. The flies captured in the traps were sexed, counted and removed after each check. The traps were replenished with fresh bait at fortnightly intervals and the experiment was continued for 50 days. During renewal, all the old baits of Plastic Multilure Traps (MLT) were collected in a plastic bucket and buried outside the experimental orchard to avoid interference with traps. The following chemicals were evaluated:

(1) MLT, trap with 300 ml solution containing Nulure (9 %).
(2) MLT trap with Ammonium Acetate (AA) 1 patch, Putrescine (PT) 2 patches
(3) MLT trap with AA 2 patches
(4) MLT trap with AA 1/2 patch
(5) MLT trap, with AA 1/2 patch, PT 2 patches
(6) MLT trap with AA 1 patch, PT 2 patches, Trimethylamine (TMA) 1 patch
(7) MLT trap with, PT 2 patches, 3 tablets of Torula yeast
(8) MLT trap with, Di-ammonium phosphate (DAP) and protein hydrolysate (PRH) at a 7:3 ratio in 100 ml water
(9) MLT trap with DAP 10g in 100ml water
(10) LOCAL Trap, Methyl Eugenol 4ml

2.2. Evaluation of Torula Yeast and Ammonium Carbonate to attract *B. zonata* females

Five different baits were evaluated in MLT traps to attract *B. zonata* females using a randomized complete block design with four replicates per treatment. The experiment was conducted in a guava orchard on an area of 20 hectares. The experimental site was divided in four blocks and each block was used as a replicate. All the baits were received from the IAEA except Di-ammonium Phosphate together with a complete research protocol. No spray of any insecticide was done in the orchard during the experimental period. The traps were hung horizontally in the upper two thirds of the south - eastern part of the guava tree at a uniform distance (30-35 meters apart from each other) at the height of about 2.5 m above the ground level on the trees. Trap catches were recorded twice a week (3 to 4 days interval) and the traps within the blocks were rotated sequentially after each reading. The flies captured in the traps were sexed, counted and removed after each check. The traps were replenished with fresh bait at fortnightly intervals and the experiment was continued for 50 days. During renewal, all the old baits of MLT traps were collected in a plastic bucket and buried outside the experimental orchard to avoid interference with traps. The following chemicals were used as bait to attract the fruit flies:

(1) MLT traps with 3 tablets of Torula yeast in 300 ml water (borax already included in the tablets).
(2) MLT traps with Ammonium Bicarbonate (27g as Agrisense tablet) and Putrescine (2 ml) in 300 ml of water and two drops of Triton.
(3) MLT traps with 300 ml solution of Nulure (9%)
(4) MLT traps with Methyl Eugenol 4ml, 300ml water and two drops of Triton
(5) MLT traps with NuLure, Di-ammonium Phosphate (21g), 300 ml water and two drops of Triton

2.3. Evaluation of Borax, Casein, Rose Oil and Di-ammonium Phosphate to attract *B. zonata* females

Seven different baits were evaluated in plastic cylindrical traps (local having 2.5 litres capacity) in a randomized complete block design using three replicates per treatment. The experiment was conducted in a mango orchard on an area of 40 hectares. The experimental site was divided in three blocks and each block was used as a replicate. All the baits were purchased locally. No spray of any insecticide was done in the orchard during experimental period. The traps were hung horizontally in the upper two thirds of the south - eastern part of the mango tree at a uniform distance (30-35 meters apart from each other) at the height of about 2.5m above the ground level on the trees. Trap catches were recorded twice a week (3 to 4 days interval) and the traps within the blocks were rotated sequentially after each reading. The flies captured in the traps were sexed, counted and removed after each check. The traps were replenished with fresh bait at fortnightly intervals and the experiment was continued for 66 days. During renewal, all the old baits of the local plastic traps were collected in a plastic bucket and buried outside the experimental orchard to avoid interference with traps. The following chemicals were used as bait to attract the fruit flies:

(1) Local trap with NuLure (9%), Di-ammonium phosphate (21g)
(2) Local trap with borax (3g), Di-ammonium phosphate (21g), Rose Oil (3ml)
(3) Local trap with, Casein (3g), Di-ammonium phosphate (21g)
(4) Local trap with Casein (3g), Rose Oil (3ml)
(5) Local trap with Methyl Eugenol (ME) (3ml), Casein (3g), Di-ammonium Phosphate (21g)
(6) Local trap with ME (4ml), borax (3g)
(7) Local trap with Casein (3g), borax (3g)

2.4. Responses of *B. zonata* males and females to different coloured traps

Different coloured traps baited with 5ml mixture of NuLure and diammonium phosphate in a 3:7 ratio were hung on mango trees at a hight of 2.5m above the ground level. An insecticide Fyfanon-57 EC was also added in the solution to kill the attracted flies. Five ml of the mixture was injected into cotton wicks and one wick was placed inside each trap on a wire loop. Trap catches were recorded twice a week and the traps within a block were rotated sequentially after each reading. The flies captured in the traps were sexed, counted and removed. The traps were replenished with fresh bait at fortnightly intervals and the experiment was continued for 120 days.

2.5. Management of Peach fruit fly through eco-friendly techniques

Attractants can be used for male annihilation technique (MAT) and for bait spray technique (BAT). These are used either singly or in combination. The attractants are also coupled with other control measures such as conventional insecticides and sanitation in the orchards. MAT has been used effectively either alone or in combination with the bait spray technique. Different environment friendly techniques (MAT, BAT and cultural practices alone or in combinations) were applied in guava orchards at Nawazabad Farm, (40 hectares) and Habib Farm, (12 hectares). The BAT used consists of 2% protein hydrolysate and 0.7% Malathion 57 EC. The MAT was applied by using plywood blocks of 50mm x 50mm x 12 mm, each containing 6g of ME and 1g of Malathion 57 EC. The plywood blocks impregnated with the toxic-lure mixture (6ml) was applied at monthly intervals through out the year in the respective orchards. The cultural practices included the picking and disposing of the dropped fruits at fortnightly intervals along with ploughing whenever necessary. The cultural treatments were applied separately or in conjunction with other techniques. For application of the different treatments, the orchard was divided in five different blocks at each experimental site. The infestation of fruit flies was recorded by sampling and dissecting at least fifty fruits from four different places for each treatment. The population of fruit flies was observed by placing one ME baited trap 2/ha for each treatment.

3. RESULTS

3.1. Evaluation of Ammonium Acetate, Putrescine and Trimethyl-amine to attract *B. zonata* females

All the tested chemicals attracted both sexes of the fruit flies in variable numbers. The ME attracted only males and not a single female was trapped in these traps. The percentage of female catches was comparatively higher in the traps baited with AA+PT than in the other attractants. None of the chemical captured male flies up to the level of ME. The relative trapping efficiency of ME baited traps was also higher followed by the AA and PT and double quantity of AA (Table I). Results revealed that AA showed more potential to attract the female fruit flies as compared to the NuLure, Torula yeast, TMA, etc. Di-ammonium phosphate and NuLure captured the lowest number of female fruit flies among the tested chemicals. The catches of females were higher than the males in all the tested baits except ME, which captured only males. It was observed that 300ml water and 2 drops of Triton proved to be a good retention system. The attractant AA in combination with ME is being tested in a single trap to attract both sexes of *B. zonata*.

TABLE I. PEACH FRUIT FLY (*B. ZONATA*) CAPTURED WITH DIFFERENT ATTRACTANTS.

Treatments	Males	Females
NuLure	45.8 ^{c}	78 ^{f}
Ammonium Acetate (AA)	15.0 ^{cd}	270.7 ^{b}
AA + Putrescine (PT)	11.3 ^{d}	370.5 ^{a}
AA	30.0 ^{cd}	198.7 ^{d}
AA + PT	11.2 ^{d}	230.3 ^{c}
A.A + PT + TMA	4.5 ^{d}	258.7 ^{b}
PT + Torula yeast	104.3 ^{b}	173.3 ^{e}
Di-ammonium phosphate (DAP)	14.2 ^{cd}	69.8 ^{f}
NuLure + DAP	26.3 ^{cd}	213.7 ^{d}
Methyl Eugenol	1029.0 ^{a}	0.0 ^{g}

3.2. Evaluation of Torula yeast and Ammonium Carbonate to attract *B. zonata* females.

All the tested chemicals attracted both sexes of *B. zonata* in variable numbers. However, ME baited traps attracted only males and not a single female was trapped. The percentage of female catches was higher in the traps baited with the combined NuLure and Di-ammonium Phosphate (DAP) in a 3:7 ratio followed by Torula yeast with no statistical difference among them. Apart from ME, Torula yeast captured the highest number of males and total males plus females (Table II). Whereas, maximum number of males was captured in ME baited traps. Low trap efficiency for capturing male and females was recorded in the traps baited with NuLure. None of the attractants captured as many males as the ME, which was almost 10 times higher than the Torula yeast baited traps.

3.3. Evaluation of Borax, Casein, Rose Oil and Di-ammonium Phosphate to attract *B. zonata* females

Results indicated that all the tested chemicals attracted both sexes of *B. zonata* in variable numbers. However, combination of ME with protein baits attracted higher number of males than females (Table III). The percentage of female catches was higher in the traps baited with NuLure and Di-ammonium phosphate (DAP) followed by a combined bait of DAP + Rose Oil + borax,. Whereas, minimum number of males and females were catched in the traps baited with Casein and Rose Oil. Adding protein baits to the ME resulted in some female catches but low catches as compared with traps baited with NuLure and DAP.

TABLE II. PEACH FRUIT FLY, (*BACTROCERA ZONATA)* CAPTURED WITH DIFFERENT ATTRACTANTS.

Treatments	Males	Females
Torula yeast	696.0 ^{a}	260.0 ^{a}
Ammonium bi-carbonate	158.0 ^{bc}	109.5 ^{b}
NuLure	123.5 ^{cd}	101.5 ^{b}
Methyl eugenol	6581.5 ^{a}	0.0 ^{c}
NuLure + Di-ammonium phosphate	184.5 ^{b}	283.0 ^{a}

TABLE III. PEACH FRUIT FLY (*B. ZONATA*) CAPTURED WITH DIFFERENT ATTRACTANTS.

Treatments	Males	Females
NuLure + Di-ammonium phosphate (DAP)	197.2 ^{c}	288.7 ^{a}
DAP + Rose Oil + Borax	55.5 ^{d}	143.3 ^{b}
Casein + DAP + NuLure	39.8 ^{d}	91.5 ^{c}
Casein + DAP	21.7 ^{d}	16.5 ^{f}
Methyl Eugenol (ME) + Casein + DAP	1988.0 ^{a}	27.7 ^{ef}
ME + Borax	1758.5 ^{b}	42.0 ^{de}
Casein + Borax	44.5 ^{d}	53.5 ^{d}

3.4. Responses of *B. zonata* males and females to different coloured traps

Results indicated that trap colour affected the catches of *B. zonata* fruit flies. Maximum numbers of fruit flies were captured in local Tando Jam transparent traps followed by yellow coloured traps, whereas, minimum numbers of the flies were captured in blue and red coloured traps. The trend of catches of fruit flies during the test period was identical in all traps (Table IV). The transparent and yellow captured comparatively more numbers of females than the other coloured traps. While blue and red coloured traps captured few number of females.

TABLE IV. PEACH FRUIT FLY (*B. ZONATA*) CAPTURED IN DIFFERENT COLOURED TRAPS BAITED WITH NULURE AND DI-AMMONIUM PHOSPHATE

Month	Yellow		Dark Green		Light Green		Orange		Red		Blue		White		Transparent	
	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M
June	31	90	46	94	48	116	12	98	16	82	16	101	7	126	72	141
July	164	189	103	118	88	77	22	31	3	83	17	61	14	191	133	261
Aug.	133	192	28	68	19	41	17	59	1	54	0	42	11	212	204	334
Sept.	84	108	0	17	1	22	11	41	0	41	0	10	3	144	133	233

F= Female M= Male

3.5. Management of Peach Fruit Fly through eco-friendly techniques

Based on adult catches in traps and fruit infestation, male annihilation technique (MAT) in conjunction with bait spray and cultural practices proved significantly more effective for the control of peach fruit fly in guava orchards as compared to the other treatments. Fruit fly catches and fruit infestation where bait sprays in combination with cultural practices was used was higher than any other treatment except for the control (Table V). Higher catches of fruit fly adults in ME baited traps and fruit infestation levels were recorded at Nawazabad Farm than Habib Farm. Similar results in pupal recovery of the dropped fruits were recorded from mango orchards (Table VI).

TABLE V. EFFICACY OF DIFFERENT ECO-FRIENDLY TECHNIQUES FOR THE MANAGEMENT OF PEACH FRUIT FLY IN GUAVA ORCHARDS.

	Locations			
Treatments	Nawazabad Farm, Mirpurkhas		Habib Farm, Hyderabad	
	Male catches	Fruit infestation	Male catches	Fruit infestation
MAT + BAT	2.7 ^{d}	3.83 ^{d}	1.84 ^{de}	2.11 ^{e}
MAT + BAT + Cultural practices	1.0 ^{d}	0.47 ^{e}	0.91 ^{e}	0.13 ^{f}
MAT + Neem spray	5.2 ^{d}	8.19 ^{c}	3.42 ^{d}	9.71 ^{d}
BAT + Cultural practices	22.7 ^{b}	14.67 ^{b}	21.63 ^{b}	13.50 ^{b}
Insecticide	13.6 ^{c}	9.32 ^{c}	17.21 ^{c}	10.59 ^{c}
Control (No treatment)	37.3 ^{a}	41.93 ^{a}	36.27 ^{a}	39.57 ^{a}

TABLE VI. EFFICACY OF DIFFERENT ECO-FRIENDLY TECHNIQUES FOR THE MANAGEMENT OF PEACH FRUIT FLY IN MANGO ORCHARDS.

Treatments	Locations: Nawazabad Farm, Mirpurkhas		Habib Farm, Hyderabad	
	Male catches	Fruit infestation	Male catches	Fruit infestation
MAT + BAT	2.00 e	1.01 e	1.6 d	1.10 e
MAT + BAT + Cultural practices	0.12 f	0.03 f	0.5 e	0.01 f
MAT + Neem spray	5.55 d	2.37 d	4.4 c	4.34 d
BAT + Cultural practices	11.75 b	9.69 b	5.5 c	9.15 b
Insecticide	7.71 c	6.86 c	10.1 b	5.65 c
Control (No treatment)	16.08 a	12.49 a	15.2 a	19.18 a

4. DISCUSSION

Trapping plays an important role in insect pest control programmes for monitoring of established populations and for early detection of newly introduced species in a particular area. Different protein baits were used for trapping both sexes of *B. zonata.* Ammonium Acetate in combination with Putrescine (PT) and water/Triton and NuLure 9% (hydrolysate protein) in combination with Di-ammonium Phosphate (DAP) appeared to be the best treatments for attracting *B. zonata* females. Barnes and Osborn [11] developed a dry sticky trap consisting of a sticky food carton baited with powdered ammonium carbonate for the attraction of Walnut Husk fly. Whereas, Seewooruthun, *et al.,* [12] collected female flies of *B. dorsalis* in McPhail traps baited with ammonium chloride. The combining effect of AA with DAP was negatively correlated with the attraction of the females. The Multilure (MLT) trap baited with Ammonium Bicarbonate (Agrisense tablet) and PT in 300 ml of water and two drops of Triton showed poor performance in attracting the flies. Studies indicated that food based synthetic chemicals attracted more number of females of *B. zonata* as compared to the NuLure alone. These results are consistent with what was reported by Heath *et al,* [14] for *C. capitata*. In relation to trap colour, the best performance for capturing the peach fruit fly was obtained with transparent traps followed by yellow coloured traps.

5. CONCLUSIONS

Present studies showed significant progress in developing a female attracting system for *B. zonata.* Based on these findings it is apparent that synthetic food attractants provide an effective system for capturing the peach fruit fly. Furthermore, research is required to evaluate the potential use of these attractants in mass trapping strategies for control of feral females, in addition to the male annihilation technique. The present studies are definitely a step forward in this direction.

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DEVELOPMENT OF FEMALE ATTRACTANTS WITH LOCAL FOOD-BASED CHEMICALS FOR *Bactrocera zonata* (SAUNDERS)

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Abstract

Among tephritid fruit flies, the peach fruit fly, *Bactrocera zonata* (Saunders), is the most destructive pests of many fleshy fruits in Pakistan. Although several male trapping systems are available for the peach fruit fly, *Bactrocera zonata*, female attracting systems are not available yet. Studies conducted indicated that among the thirty two female targeted attractants evaluated, protein hydrolysate (NuLure) in combination with Di-ammonium Phosphate (DAP) in a 3:7 ratio attracted the highest number of female flies followed by NuLure + DAP 4:6 and NuLure + DAP 1:9. However, male catch was comparatively higher than female catch in the traps. Studies indicated that trap design also played a significant role for attracting fruit flies and the close bottom dry traps having two holes on each side captured the maximum numbers.

1. INTRODUCTION

Fruits are grown on an area of 657,000 hectares with an annual production of 5 million tonnes in Pakistan [1]. Fruit flies are the most destructive pests of the fruits grown through out the world. Among various species of fruit flies, the peach fruit fly, *Bactrocera zonata* (Saunders), is the predominant species attacking peach, guava, mango and other fleshy fruits in Pakistan. Its control largely depends on the application of broad spectrum insecticides, which pose potential health risks to people living in the rural areas, destruction of beneficial insects and development of insect pest resistance. Research on fruit flies is therefore, geared towards development of alternative control strategies. A number of alternative and novel methods of pest control are being developed and implemented throughout the world. Among alternative methods of insect control in fleshy fruits, male annihilation technique (MAT) and bait sprays (BAT) alone or in conjunction with the Sterile Insect Technique (SIT), seem to have great potential. A programme for area-wide management of *B. zonata* using MAT was initiated in the Sindh province of Pakistan by Qureshi *et al.* [2]. However, the lure used for MAT application (Methyl Eugenol) is male specific. Development of female attracting system of *Bactrocera* spp. would be a major breakthrough for fruit fly area-wide management programmes. Food attractants such as molasses, fermented sugar and yeast's have been used to attract the fruit flies. Subsequently, protein hydrolysate was used as well as Torula yeast, being the latter easier to manage and standardize [3]. Protein hydrolysate has been the most potent attractant for both sexes of Medfly and *Anastrepha ludens* [4]. Mazori *et al.* [5] reported that combination of Ammonium Acetate with Putrescine and Trimethylamine, captured the females *Ceratitis capitata* effectively. Whereas, Epsky *et al*. [6] developed an efficient attractant for *A. suspensa* based on borax and protein hydrolysate in McPhail traps.

Use of bait in combination with a toxicant to suppress or eradicate potentially damaging population of fruit flies commenced as early as 1908, in South Africa. The concept of a bait spray is to attract the flies to droplets of the mixture, where they feed and die [7]. Until 1952, the principal baits used for medfly were sugars, molasses, syrups or other sorts of carbohydrates. However, in the 1950's, enzymatic protein hydrolysates were found to be more attractive to medflies than carbohydrates [8]. One particular bait spray which was adopted in the 1960's remains the standard today in many countries. It consists of a mixture of protein bait plus malathion for fruit fly suppression mainly medfly [9]. Nevertheless, very little information is available for monitoring and controlling *B. zonata* using female targeted products, thus feasibility studies need to be conducted. Therefore, the present studies were planned to develop a female attracting system of *B. zonata* using the locally available food-based chemicals.

2. MATERIALS AND METHODS

2.1. Evaluation of different chemicals to attract both sexes of *B. zonata*

Thirty two baits of different chemicals alone or in combination with each other consisting of Ammonia, NuLure (protein hydrolysate), Casein, Methyl Eugenol (ME), Boric Acid and Rose Oil were tested for the attraction of both sexes of *B. zonata*. The chemicals were applied alone or in combinations, after mixing them in different proportions in 100ml of water. Five percent insecticide, Fyfanon 57 EC was added in the solution as a killing agent. Five ml of the mixture was injected into cotton wick and placed inside the trap on a wire loop. The locally designed traps consisted of cylindrical plastic container of 2 liters capacity with screwed lid, having two holes of 4 cm diameter on each side (top & bottom) fitted in a 8.5 cm long piece of PVC pipe at each hole to prevent flies from escaping. The traps were suspended horizontally at about 2.5 m above the ground level on the fruit trees in the guava orchards in three blocks at different localities. The flies captured in the traps were sexed, counted and removed twice a week and the traps within a block were rotated sequentially after each reading. The traps were replenished with fresh bait at fortnightly intervals and the experiment was continued for 168 days during the peak infestation period.

2.2. Evaluation of trap design for efficient trapping of *B. zonata*

Five different types of traps were evaluated for catches of *B. zonata* (1) Closed bottom dry trap (CBD) (6" diameter and 9" long) with two holes on the peripheral side fitted with 1.5cm long pieces of PVC pipe of 3.25cm diameter in each hole to prevent the escape of captured flies, (2) closed bottom dry trap with three holes, (3) closed bottom dry trap with four holes (4) Jackson trap and (5) plastic cylindrical trap. Traps were baited with the six attractants, which showed to be effective for the catches of both sexes of *B. zonata* in the above-mentioned experiment. Traps were replenished with new attractant at fortnight intervals. The traps were hung on guava trees at about 2.5m above the ground level. The white sticky insert of Jackson trap was changed on each observation. Trap catches were recorded twice a week and the traps within a block were rotated sequentially after each observation. Flies were sexed and counted to record the preference of traps for each sex.

3. RESULTS AND DISCUSSION

3.1. Evaluation of different chemicals to attract both sexes of *B. zonata*

All the tested chemicals attracted both sexes of the fruit flies in variable numbers. However, six chemicals proved more effective than the others and captured higher number of flies. The chemical protein hydrolysate (NuLure) + Di-ammonium Phosphate (DAP) using a 3:7 ratio (PRH-DAP-3:7) captured the highest number of female flies as compared to the rest of the chemicals, followed by PRH + DAP-4:6 and PRH + DAP-l:9 (Table I). However, more males than females were captured in all the chemicals tested. Results indicated that the mixtures of NuLure and DAP attracted more number of females as compared to other combinations. The mixture of NuLure + DAP at a 3:7 ratio gave the best results for both females and males. It was observed that with the addition of Methyl Eugenol in any of the chemicals tested the catches of male flies dominated which resulted in decrease of female fly catches. Ammonia and protein hydrolysate showed some potential to attract the females of *B. zonata.* Therefore, more efforts need to be applied in optimizing the use of these compounds to enhance the efficiency of female *B. zonata* trapping systems.

3.2. Evaluation of trap design for efficient trapping of *B. zonata*

Results indicated (Table II) that the closed bottom dry trap (CBD) with two holes captured the highest number of fruit flies per trap followed by standard Tandojam Trap. The Jackson trap captured the minimum number of fruit flies. The catches of both sexes of the fruit flies were higher when the CBD was baited with PRH-DAP-3:7 followed by PRH-DAP-2:8. However, the catches showed some selectiveness with the trap design and chemicals used. The chemical bait PRH-DAP-3:7 showed the best performance in closed bottom dry traps with two holes, whereas, the bait PRH-DAP-2:8 showed the best in closed bottom dry traps having three holes. These results suggest that the chemical bait PRH-DAP-3:7 in closed bottom dry traps having two holes is the best choice as a trapping system for monitoring *B. zonata* female populations in the field.

TABLE I. CAPTURE OF BOTH SEXES OF PEACH FRUIT FLY, *BACTROCERA ZONATA* (SAUNDERS), USING DIFFERENT CHEMICALS ALONE OR IN COMBINATION.

Name of chemicals	Average flies captured/week			Relative trapping efficiency (%)	
	Male	Female	Total	Male	Female
PRH-DAP-9:1	13.4	11.3	24.7	0.49	6.08
PRH-DAP-8:2	10.1	9.3	19.4	0.37	5.01
PRH-DAP-7:3	13.7	12.1	25.8	0.50	6.51
PRH-DAP-6:4	6.5	6.5	13.0	0.24	4.50
PRH-DAP-5:5	12.9	13.6	26.5	0.47	7.32
PRH-DAP-4:6	17.7	15.5	33.2	0.64	8.34
PRH-DAP-3:7	32.3	25.7	58.0	1.72	13.85
PRH-DAP-2:8	13.5	12.0	25.5	0.49	6.46
PRH-DAP-1:9	17.4	15.3	32.7	0.63	8.23
CA-DAP-9:1	3.6	2.5	6.1	0.13	1.34
CA-DAP-8:2	5.7	5.0	10.7	0.21	2.69
CA-DAP-7:3	6.7	5.5	12.2	0.24	2.96
CA-DAP-6:4	5.5	3.7	9.2	0.20	1.99
CA-DAP-5:5	8.7	7.0	15.7	0.32	3.77
CA-DAP-4:6	8.3	6.8	15.1	0.30	3.66
CA-DAP-3:7	7.1	6.9	14.0	0.26	3.71
CA-DAP-2:8	10.5	8.7	19.2	0.38	4.68
CA-DAP-1:9	12.0	9.4	21.4	0.44	5.06
AMA-10	0.8	0.5	1.3	0.03	0.27
DAP-10	3.3	2.3	5.6	0.12	1.24
PRH-10	0.6	0.6	1.2	0.02	0.32
CA-10	0.8	0.3	1.1	0.03	0.16
AMA-PRH-5.5	1.4	1.1	2.5	0.05	0.59
AMA-BA-5.5	0.9	0.8	1.7	0.03	0.43
BA-ME-5.5	1249.2	0.3	1249.5	45.33	0.16
AMA-ME-5.5	721.9	0.2	722.1	26.19	0.11
ME	569.3	0.8	570.1	20.66	0.43
BA-RO-5.1	0.7	0.2	0.9	0.03	0.11
BA-PHR-RO-5.5.1	0.0	0.0	0.0	0.00	0.00
BA-DA-RO-5.5.1	0.5	1.0	1.7	0.02	0.53
BA-AMA-RO-5.1.1	0.0	0.0	0.0	0.00	0.00
AMA-MO-5.5	0.9	0.9	1.8	0.03	0.48
	2755.9	185.6		100.0	100.0

PRH - Protein hydrolysate; DAP Di-ammonium phosphate; CA - Casein; ME - Methyl Eugenol; AA- Ammonium Acetate; BA – Borax; RO - Rose oil, MO - Molasses

TABLE II. EFFECT OF DIFFERENT TRAPS AND TREATMENTS ON THE CATCHES OF BOTH SEXES OF THE PEACH FRUIT FLY, *BACTROCERA ZONATA* (SAUNDERS).

Trap design	*B. zonata* captured/trap/week			Other species
	Males	Females	Total	
Bait 1				
CBD 2-Holes	437 [a]	358 [ab]	795	--
CBD 3-Holes	416 [a]	305 [b]	721	--
CBD 4-Holes	475 [a]	473 [a]	1088	--
Jackson	89 [c]	78 [c]	167	--
Cylindrical	269 [b]	255 [b]	524	--
Bait 2				
CBD 2-Holes	563 [b]	512 [ab]	1075	--
CBD 3-Holes	798 [a]	634 [a]	1432	--
CBD 4-Holes	552 [b]	432 [b]	1159	--
Jackson	69 [d]	52 [c]	121	--
Cylindrical	518 [b]	456 [b]	974	--
Bait 3				
CBD 2-Holes	877 [a]	780 [a]	1657	--
CBD 3-Holes	652 [b]	540 [bc]	1192	--
CBD 4-Holes	615 [b]	607 [b]	907	--
Jackson	161 [c]	163 [d]	324	--
Cylindrical	856 [a]	699 [a]	1555	--
Bait 4				
CBD 2-Holes	550 [b]	496 [a]	1046	--
CBD 3-Holes	486 [c]	421 [ab]	907	--
CBD 4-Holes	639 [a]	472 [a]	1111	--
Jackson	73 [d]	67 [c]	140	--
Cylindrical	522 [b]	412 [b]	934	--
Bait 5				
CBD 2-Holes	617 [a]	446 [a]	1063	--
CBD 3-Holes	309 [c]	246 [bc]	555	--
CBD 4-Holes	295 [d]	306 [b]	601	--
Jackson	72 [e]	55 [d]	127	--
Cylindrical	487 [b]	341 [b]	828	--
Bait 6				
CBD 2-Holes	435 [a]	292 [a]	727	--
CBD 3-Holes	309 [b]	246 [ab]	555	--
CBD 4-Holes	228 [c]	230 [b]	458	--
Jackson	22 [d]	23 [c]	45	--
Cylindrical	335 [b]	267 [a]	602	--

Bait 1 Protein hydrolysate + Di-ammonium phosphate in 1:9 ratio (PRH-DA-1:9)
Bait 2 Protein hydrolysate + Di-ammonium phosphate in 2:8 ratio (PRH-DA-2:8)
Bait 3 Protein hydrolysate + Di-ammonium phosphate in 3:7 ratio (PRH-DA-3:7)
Bait 4 Protein hydrolysate + Di-ammonium phosphate in 4:6 ratio (PRH-DA-4:6)
Bait 5 Protein hydrolysate + Di-ammonium phosphate in 5:5 ratio (PRH-DA-5:5)
Bait 6 Protein hydrolysate + Di-ammonium phosphate in 7:3 ratio (PRH-DA-7:3)
CBD = Close bottom dry trap

4. CONCLUSIONS

Results of these field trials showed significant progress in developing a trapping system capable of catching female *B. zonata*. Traps with closed bottom and two holes baited with protein hydrolysate (NuLure) + Di-ammonium Phosphate (DAP) at a 3:7 ratio proved satisfactory for monitoring *B. zonata* populations. Research efforts need to be made to evaluate the potential for use of this trapping system in mass trapping strategies of feral females.

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EVALUATION OF FOOD-BASED ATTRACTANTS FOR FRUIT FLY TRAPPING IN MAURITIUS

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Abstract

Among tephritid fruit flies, *Bactrocera zonata* and *B. cucurbitae* are the most destructive pests of tree fruits and cucurbits, respectively, in Mauritius. A feasibility study is ongoing with technical and financial assistance from the International Atomic Energy Agency (IAEA), Joint FAO/IAEA Programme, on integrated management of fruit flies using the Sterile Insect Technique (SIT). Management of fruit flies by SIT or other techniques require population estimation methods which accurately reflect changes in population levels. While male specific sexual lures have been quite effective in monitoring population levels, depending on the fruit fly species, female attractants have been less effective. A trapping system geared towards female flies would be a good tool for improving the efficacy of integrated fruit fly management including SIT and monitoring its effectiveness. A Co-ordinated Research Project (CRP) was implemented by the FAO/IAEA from 2000 to 2005. The CRP had the objective of developing and comparing female trapping systems for use in combination with bait application technologies and SIT, and to provide a standardized surveillance system among fruit fly pest species and regions. Trials were conducted in different geographical and ecological regions. Mauritius was one of the 15 participating countries. While studies in Mauritius focused mainly on *Bactrocera zonata* and *B. cucurbitae*, other fruit fly species were also taken into consideration. Trials were conducted in four phases. Trapping trials targeting *B. zonata* were set out in backyards with a variety of fruit trees as hosts while trials with *B. cucurbitae* were carried out in growers' cucurbit plantations. The CRP compared the use of different food attractants such as NuLure, Torula Yeast, Ammonium Bicarbonate (AB), Ammonium Phosphate (AP), Ammonium Acetate (AA) and Ammonium Sulphate (AS) and the three component lure AA, PT and Trimethylamine (TMA) in different combinations. Food attractants, namely protein hydrolysate, Torula Yeast and GF120 were also tested. In the Phase I trials, the food attractants Torula Yeast and NuLure were found to be more effective in capturing *B. zonata*, *B. cucurbitae*, *Ceratitis rosa* or *C. capitata* as compared to traps baited with AA. The three component lures, AA+PT+TMA (Biolure) performed better than the single AA attractant in capturing females *B. zonata* or *B. cucurbitae* in the Phase II and III trials. The three component lure (Biolure) was also the most effective attractant for *C. rosa* and *C. capitata.* No significant difference was obtained among the treatments comprising of different combinations of the three component lures as compared to other food attractants such as protein hydrolysate or GF120 in Phase IV trials. The synthetic food attractants based on AA alone or in combination with other attractants, appear to be a more effective and selective option for fruit fly surveillance including *B. zonata*, *B. cucurbitae*, *Ceratitis rosa* and *C. capitata*, than the more conventional hydrolysate protein NuLure and the Torula yeast.

1. INTRODUCTION

Fruit flies are known to be important pests of horticultural crops worldwide with the main genera, *Anastrepha*, *Ceratitis*, and *Bactrocera* infesting over 300 species in tropical, subtropical and temperate climates. Control efforts have evolved from blanket spraying using chemicals to more sophisticated and environment friendly control method that integrates different measures such as bait application, male annihilation, biological control and the Sterile Insect Technique (SIT) [1, 2, 3, 4].

SIT has been used successfully for the suppression, eradication, containment and prevention of some species of fruit flies [5, 6]. It is also viewed as a non-polluting and cost-effective means of fruit fly management, especially in integrated management systems. Monitoring of populations is an important prerequisite of any control programme, including SIT and precise and effective methods are therefore required.

In Mauritius, fruit flies have been the subject of research and control for many years [7, 8, 9, 10, 11]. Eradication of *Ceratitis rosa* had been attempted in 1980 [12] using SIT. An incursion of *B. dorsalis* was successfully eradicated in 2000 [13] using mainly Bait Application Technique (BAT) and Male Annihilation Technique (MAT). Fruit fly control is currently based on area-wide management, using BAT and MAT [14, 15]. An action programme was initiated in 1994 with technical and financial assistance from the European Union, under the European Communities Lome IV Convention [10] and is now being continued through government funding. Control actions are implemented in major fruit growing areas and are mainly directed at backyard fruit production where most of the fruits are produced, there being very few organized orchards. The possibility of eradicating the main fruit fly pest of tree fruits, *Bactrocera zonata*, has been contemplated as a more permanent method. A feasibility study is ongoing under IAEA TCP MAR 5/015.

Monitoring of fruit fly population levels has been ongoing since 1992 [14]. It is an integral part of the current area-wide programme and will also be a prerequisite of the envisaged SIT programme. At present, monitoring is conducted essentially through the use of dry traps baited with male specific sexual attractants and partly with protein hydrolysate in McPhail traps which catches both females and males. However, the development of effective more specific female attractants would greatly enhance the SIT programme both for monitoring and for use as a population suppression measure through mass trapping.

The melon fly, *B. cucurbitae*, is an important pest of cucurbits and control actions by growers are mainly dependant on chemical measures. However, an integrated management programme is being developed [16, 17] and recommended.

A Co-ordinated Research Project (CRP) was conducted from 2000 to 2005 on "Development of Improved Attractants and their Integration into Fruit Fly Management Programmes" under FAO and IAEA Joint Programme. The CRP involved 15 countries from different geographical and ecological situations over the five continents, Mauritius being one of them. The objective of the CRP was to develop new synthetic female biased attractants and to determine their efficacy for different fruit fly species, thus providing an opportunity to enhance control strategies, to develop bait stations for integration with SIT management programmes, and to provide standardized trapping systems among regions. This CRP was complementary to a previous CRP entitled "Development of female medfly attractant systems for trapping and sterility assessment" conducted between 1995 and 1998 [19]. The female medfly attractants developed were tried for different species of fruit flies and tested in different combinations against other food attractants.

2. MATERIALS AND METHODS

The trials were conducted in four phases over the five year period. Participating countries were divided into three groups, the Latin American, the Mediterranean and the Indian Ocean groups. The Latin American group worked on *Anastrepha* sp. while the other two groups directed studies on *Bactrocera* sp. and *Ceratitis* sp. In Mauritius, our studies were concentrated on *B. zonata* and *B. cucurbitae*.

For studies on *B. zonata*, traps were set mainly in backyard fruit trees as experimentation in proper orchards was not possible, there being very few of these. However, a variety of fruit trees are found in the selected sites. Trials on *B. cucurbitae* were conducted in fields where different species of cucurbit crops are grown.

Trapping was carried out as per an agreed protocol, common for the Mediterranean and Indian Ocean groups, over a period of eight weeks.

Traps were hung on fruit trees, 1 to 2 meters above the ground, in the lower half of the south-eastern part of the tree canopy. At each site, traps (Multilure traps (plastic McPhail type traps)) were set in five lines of seven traps. The distance between two traps varied between 25 to 50 m in any one line. Traps were serviced twice a week and all tephritids and beneficial insects captured were collected in 70% alcohol. Fruit flies were identified, sexed and recorded. After data collection, traps within a line were rotated sequentially. During weekly renewal, the old liquid baits of 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. A sample of the females collected by each bait was dissected to determine their fertility status.

In cucurbit fields, traps were hung on wooden poles at a height of about 30 cm above the ground level.

Trap catches were *log* transformed prior to analysis of variance and means were separated with least significant test.

2.1. Phase I

2.1.1. Sites of Study

Two sites were selected for experimentation on *B. zonata*, namely Mahebourg and Pointe aux Sables. Mahebourg lies near the South-eastern coast of the island, at an altitude of 10 to 30 metres ASL, while Pointe aux Sables is in the Western part at an altitude of 5 to 20 metres ASL. Fruit fly hosts at the two sites were guava, peach, loquat, mango and Indian almond.

Trials for *B. cucurbitae* were laid out in fields at Plaine Sophie and Bel Air, both in the central part of the island, at about 550 m, where contiguous plots were planted with pumpkin, snakegourd and bittergourd.

2.1.2. Traps and Attractants

The trial consisted of seven treatments replicated five times in a randomized block design. The treatments were as follows:

(i) Plastic Multilure McPhail type trap (MLT). Bait with 300 ml of a solution containing 9% NuLure, 3% borax, 88% water (by weight).
(ii) MLT as a wet trap. Bait with Ammonium Bicarbonate (AB), 300 ml of water and Triton (1-2 drops).
(iii) MLT as a dry trap. Bait with Ammonium Bicarbonate (AB) and DDVP.
(iv) MLT as a wet trap. Bait with 3 tablets Torula Yeast with 300 ml of waster.
(v) MLT as a wet trap. Bait with Ammonium Phosphate (AP) patch, 300 ml of water and Triton (1-2 drops).
(vi) MLT as a wet trap. Bait with Ammonium Acetate (AA) patch, 300 ml of water and Triton (1-2 drops).
(vii) Local trap (EDMA) baited with either Methyl Eugenol or Cuelure depending on the fruit fly species under study.

2.2. Phase II and III

2.2.1. Study Sites

Sites selected for *B. zonata* were Pointe aux Sables (5-20 m ASL) and Beau Bassin (290 –350 m ASL), where trials were carried out in November to December 2002 (Phase II) and repeated in January to March 2003 (Phase III). Main fruit fly hosts available during the period of experimentation were guava, peach, loquat, mango and Indian almond.

Trapping for *B. cucurbitae* were conducted at Plaine Sophie and Nouvelle Découverte, both in the central part of the island, at 540 m and 500 to 600 m ASL, respectively. Crops available were cucumber, pumpkin, ridged gourd and snake gourd, all of which are very susceptible to the melon fly.

2.2.2. Traps and Attractants

The trial consisted of seven treatments replicated five times in a randomized block design. The treatments as set up in the protocol were as follows:

(i) MLT as a wet trap. Bait with 300 ml of a solution containing 9% NuLure, 3% borax, 88% water (by weight).

(ii) MLT as a wet trap. Bait with lure Ammonium Acetate (AA) ½ patch, 300 ml of water and Triton (1-2 drops).
(iii) MLT as a wet trap. Bait with lure Ammonium Acetate (AA) 2 patch, 300 ml of water and Triton (1-2 drops).
(iv) MLT as a wet trap. Bait with Di-ammonium Phosphate (50 gms/L).
(v) MLT as a wet trap. Bait with Ammonium Sulphate (30 gms/L).
(vi) MLT as a wet trap. Bait with lure Ammonium Acetate (AA) patch, Putrescine (PT) patch, Trimethylamine (TMA) patch, 300 ml of water and Triton (1-2 drops).
(vii) MLT as a wet trap. Bait with 3 tablets Torula Yeast with 300 ml of water.

2.3. Phase IV

2.3.1. Sites of Study

Sites selected for *B. zonata* were as above (Phase II and III). Trials were carried out at Pointe aux Sables in October to December 2004 and at Beau Bassin in January to March 2005. Main fruit fly hosts available during the period of experimentation were guava, peach, loquat, mango and Indian almond.

Trapping for *B. cucurbitae* was conducted at Plaine Sophie and Bel Air, as in Phase I. Crops available were cucumber, pumpkin, ridged gourd and snake gourd.

2.3.2. Traps and Attractants

The trial consisted of seven treatments replicated five times in a randomized block design. The treatments as set up in the protocol were as follows:
(i) MLT as a wet trap. Bait with Ammonium Acetate (AA) 2 patch, Putrescine (PT) patch, 300 ml of water and Triton (1-2 drops).
(ii) MLT as a wet trap. Bait with Ammonium Acetate (AA) 2 patch.
(iii) MLT as a wet trap. Bait with protein hydrolysate (2 % v/v).
(iv) MLT as a wet trap. Bait with Ammonium Acetate (AA) 2 patch, Trimethylamine (TMA) patch,300 ml of water and Triton (1-2 drops).
(v) MLT as a wet trap. Bait with Ammonium Acetate (AA) 1 patch, Trimethylamine (TMA) patch, 300 ml of water and Triton (1-2 drops).
(vi) MLT as a wet trap. Bait with Ammonium Acetate (AA) patch, Putrescine (PT) patch, Trimethylamine (TMA) patch, 300 ml of water and Triton (1-2 drops).
(vii) Plastic Multilure (MLT) (McPhail type trap) as a wet trap. Bait with GF 120 (5%).

3. RESULTS

3.1. Phase I

Table I summarises the results obtained in Phase I. At Mahebourg, Torula Yeast captured significantly more (LSD tests, P<0.05) *B. zonata* followed by AA. Percentage of female *B. zonata* collected by AA, NuLure and Torula Yeast was 83%, 82% and 79%, respectively. In the trial at Pointe aux Sables, NuLure captured the highest number of *B. zonata*, while there was no significant difference between the trap catches of Torula Yeast and AA. There was no significant difference among the trap catches of *C. rosa* at Pointe aux Sables, while NuLure and Torula Yeast caught higher numbers at Mahebourg. At both sites, *B. zonata* was captured in higher numbers as compared to either *C. capita* or *C.* rosa. In general, Torula Yeast, NuLure and AA captured the highest number of *B. zonata, C. capitata* or *C. rosa* as compared to the other bait treatments. At Plaine Sophie, Torula Yeast captured significantly more *B. cucurbitae* followed by NuLure and AA. However, in the trial at Bel Air, AA captured significantly more females followed by Torula Yeast and NuLure. A higher number of *B.cucurbitae* was captured at Plaine Sophie as compared to trap catches at Bel Air. The percentage of females found in the traps at Plaine Sophie varied from 40 to 60% while at Bel Air it varied from 60 to 86%.

TABLE I. CAPTURES OF FEMALES PER TRAP PER DAY FOR *B. ZONATA, C.CAPITATA, C. ROSA* AND *B. CUCURBITAE* IN PHASE I.

Bait	Retention	Mahebourg (March to May 2001)	Pointe aux Sables (January to March 2002)	Mahebourg (March to May 2001)	Pointe aux Sables (January to March 2002)	Mahebourg (March to May 2001)	Pointe aux Sables (January to March 2002)	Plaine Sophie (March to May 2001)	Bel Air (January to March 2002)
		B. zonata		*C.capitata*		*C. rosa*		*B. cucurbitae*	
NuLure	Water	0.073 c	2.800 a	0.064 a	0.032 b	0.086 a	0.130	1.575 b	0.034 c
AB	Water/ Triton	0.014 d	0.618 c	0.004 d	0.011 d	0.011 d	0.030	0.175 e	0.007 de
AB	DDVP	0.006 e	0.014 d	0.000 e	0.000 f	0.003 e	0.000	0.175 e	0.006 e
AP	Water/ Triton	0.001 f	0.111 d	0.004 d	0.004 e	0.003 e	0.000	0.250 d	0.009 d
AA	Water/ Triton	0.108 b	2.225 b	0.041 b	0.025 c	0.034 c	0.130	0.507 c	0.133 a
Torula Yeast	Water	0.121 a	2.475 b	0.026 c	0.082 a	0.055 b	0.120	1.664 a	0.042 b

Means followed by the same letter in each column are not significantly different.
LSD test on transformed data Log(X+1), P=0.05
Untransformed data is shown

3.2. Phase II

Table II summarises the results obtained in Phase II. At Pointe aux Sables and Beau Bassin, the treatment with the combination of AA+PT+TMA (Biolure) captured significantly more *B. zonata* male, female or male+female flies as compared to the other treatments. The percentage of female captured by the treatment AA+PT+TMA at Pointe aux Sables and Beau Bassin was 66 % and 72 %, respectively. As regards trap catches for *C. rosa,* the treatment AA+PT+TMA captured the highest number of females at Pointe aux Sables period Nov/Dec 2002 while at Beau Bassin period Jan/Mar 2003, Di-ammonium phosphate captured significantly more females followed by AA+PT+TMA. The population of *C. capitata* was the smallest in the trials as compared to the populations of *B. zonata* or *C. rosa*. The treatment AA+PT+TMA captured significantly more female *C. capitata* at Pointe aux

Sables period Nov/Dec 2002, while there was no significant difference between female trap catches at Beau Bassin period Jan/Mar 2003. In the trials at Plaine Sophie period Nov/Jan 2003 and at Nouvelle Découverte period Feb/Mar 2003, AA+PT+TMA captured significantly more female *B. cucurbitae* than the other treatments. The percentage of females captured by AA+PT+TMA at P. Sophie and N. Découverte was 69 % and 71 %, respectively.

TABLE II. CAPTURES OF FEMALES PER TRAP PER DAY FOR *B. ZONATA, C. CAPITATA, C. ROSA* AND *B. CUCURBITAE* IN PHASE II.

Bait	Retention	Pointe aux Sables (Nov to Dec 2002)	Beau Bassin (January to March 2003)	Pointe aux Sables (Nov to Dec 2002)	Beau Bassin (January to March 2003)	Pointe aux Sables (Nov to Dec 2002)	Beau Bassin (January to March 2003)	Plaine Sophie (Nov to Dec 2002)	Nouvelle Découverte (January to March 2003)
		B. zonata		*C.capitata*		*C. rosa*		*B. cucurbitae*	
NuLure	Water	0.49 c	1.44 e	0.014 d	0.046	0.09 c	1.32 e	1.33 c	0.32 b
½ AA	Water/ Triton	0.18 f	2.45 c	0.014 d	0.036	0.05 f	1.55 d	1.10 d	0.27 c
2 AA	·/Triton	0.29 e	2.79 b	0.018 c	0.036	0.03 e	1.55 d	1.54 b	0.30 c
Di-Ammonium phosphate	Water	0.01 g	2.67 b	0.011 e	0.096	0.01 g	4.24 a	0.32 f	0.12 e
Ammonium sulphate	Water	0.34 d	0.66 f	0.018 c	0.043	0.02 d	0.50 f	0.26 g	0.07 f
AA+PT+TMA	Water/Triton	1.65 a	2.81 a	0.139 a	0.254	0.22 a	3.08 b	2.27 a	0.81 a
Torula Yeast	Water	0.85 b	2.39 d	0.093 b	0.321	0.13 b	2.34 c	0.96 e	0.16 d

3.3. Phase III

Table III summarises the results obtained in Phase III. The treatment 2AA gave the highest catches of male, female or male + female *B. zonata*, followed by Torula Yeast and ½AA at Pointe aux Sables period October to December 2003. At the 2nd site, Beau Bassin, period January to March 2004, AA+PT+TMA (Biolure) was the best treatment for catches of male, female or male + female *B. zonata*, followed by Torula Yeast and 2AA. The percentage of females per trap for the treatment AA+PT+TMA at Pointe aux Sables and Beau Bassin was 72 and 73 %, respectively. As regards to *C. capitata*, AA+PT+TMA captured significantly more females at Beau Bassin and no significant difference was observed among treatments at Pointe aux Sables. Torula Yeast showed greater attractancy for *C. rosa* at Pointe aux Sables, followed by AA+PT+TMA and NuLure, while no significant difference was found at Beau Bassin. In the trial at Bel Air, Torula Yeast out captured 2AA while at Plaine Sophie, there was no significant difference among the treatments for the captures of female *B. cucurbitae*.

TABLE III. CAPTURES OF FEMALES PER TRAP PER DAY FOR *B. ZONATA, C.CAPITATA, C. ROSA* AND *B. CUCURBITAE* IN PHASE III.

Bait	Retention	Pointe aux Sables (Oct to Dec 2003)	Beau Bassin (January to March 2004)	Pointe aux Sables (Oct to Dec 2003)	Beau Bassin (January to March 2004)	Pointe aux Sables (Oct to Dec 2003)	Beau Bassin (January to March 2004)	Bel Air (Oct to Dec 2003)	Plaine Sophie (January to March 2004)
		B. zonata		*C.capitata*		*C. rosa*		*B. cucurbitae*	
NuLure	Water	0.32 d	0.54 e	0.06	0.05 c	0.17 c	0.93	3.09 c	0.19
½ AA	Water/ Triton	0.66 b	0.68 d	0.05	0.06 b	0.08 e	0.48	3.08 c	0.33
2 AA	Water/ Triton	0.88 a	1.14 c	0.08	0.02 d	0.09 d	0.68	3.40 b	0.29
Di-Ammonium phosphate	Water	0.24 e	0.46 f	0.01	0.01 f	0.07 f	0.28	2.96 c	0.22
Ammonium sulphate	Water	0.31 d	0.47 f	0.01	0.02 e	0.06 g	0.33	1.69 e	0.22
AA+PT+TMA	Water/Triton	0.58 c	1.46 a	0.09	0.12 a	0.23 b	1.13	2.36 d	0.43
Torula Yeast	Water	0.65 b	1.20 b	0.10	0.05 c	0.27 a	0.73	4.86 a	0.34

Means followed by the same letter in each column are not significantly different.
LSD test on transformed data Log(X+1), P=0.05
Untransformed data is shown

3.3. Phase IV

Table IV summarises the results obtained in Phase IV. In the trials at Pointe and Sables and Beau Bassin, no significant difference was obtained among trap catches for *B. zonata* while the treatment 2AA+TMA caught the highest number of Females/Trap/Day (FTD). There was no significant difference in the trap catches of *C. rosa* among the different treatments. All treatments were equally effective in capturing *C. capitata.* No significant difference was observed among the trap catches of *B. cucurbitae* among the different treatments at Plaine Sophie and Bel Air. GF120 caught the highest number of flies (females, males or females+males) /Trap/Day in both trials.

4. DISCUSSION

4.1. Phase I

Percentage capture of female *B. zonata* by AA was among the highest as compared to the other treatments, both at Mahebourg (82%) and in the replicate at Pointe aux Sables (54%). The ammonia liberated from the decomposition of AA might be responsible for its attractancy towards female *B. zonata*. As far as the trials targeting *B. cucurbitae* was concerned, at high population level (first replicate at Plaine Sophie) the protein baits (NuLure and Torula Yeast) were more effective than AB, AP or AA. However, at low population level (second replicate at Bel Air), AA captured significantly more *B. cucurbitae* (females, males or females and males together) as compared to the other treatments.

TABLE IV. CAPTURES OF FEMALES PER TRAP PER DAY FOR *B. ZONATA, C.CAPITATA, C. ROSA* AND *B. CUCURBITAE* IN PHASE IV.

Bait	Retention	Pointe aux Sables (Oct to Dec 2004)	Beau Bassin (January to March 2005)	Pointe aux Sables (Oct to Dec 2004)	Beau Bassin (January to March 2005)	Pointe aux Sables (Oct to Dec 2004)	Beau Bassin (January to March 2005)	Plaine Sophie (Oct to Dec 2004)	Bel Air (January to March 2005)
		B. zonata		*C.capitata*		*C. rosa*		*B. cucurbitae*	
Torula	Water	*	2.56	*	0.06	*	1.64	*	9.08
2AA+PT	Water	0.35	2.10	0.04	0.08	0.14	1.32	7.32	8.78
2AA	Water/ Triton	0.31	1.99	0.00	0.06	0.07	0.56	6.49	8.04
Protein hydrolysate	Water/ Triton	0.04	*	0.00	*	0.05	*	4.68	*
2AA+TMA	Water	0.80	3.07	0.03	0.05	0.26	1.33	7.41	10.14
AA+TMA	Water	0.74	2.03	0.01	0.06	0.19	1.14	7.08	7.53
AA+TMA+PT	Water/ Triton	0.66	2.35	0.03	0.07	0.29	1.87	7.00	11.31
GF120	Water	0.11	0.10	0.00	0.00	0.03	0.12	10.15	11.70
Solbait	Water/ Triton	*	0.11	*	0.01	*	0.24	*	3.62

*Treatment not included
Means followed by the same letter in each column are not significantly different.
LSD test on transformed data Log(X+1), P=0.05. Untransformed data is shown

4.2. Phase II & III

In several tests, AA+PT+TMA (Biolure) was the most effective female attractant for *B. zonata, C. rosa, C. capitata* or *B. cucurbitae*. The 3 component food-based synthetic attractant performed better than the single AA attractant.

The food-based attractants tested in this study were more female specific. In tests conducted in Israel, MLT traps baited with the 3 component synthetic lure captured ≈2 times more female *C. capitata* than male in tests in citrus [19].

4.3. Phase IV

All the treatments were equally effective in capturing *B. zonata, B. cucurbitae, C. capitata or C. rosa*. However, 2AA+TMA caught the highest number of *B. zonata* while the food attractant, GF120 appeared to be more attractive to *B. cucurbitae.* The population of *C. capitata or C. rosa* in Mauritius is far lower than that of *B. zonata* as depicted by the total trap catches.

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. Different protein hydrolysates have been used for trapping both sexes of fruit flies. Ammonia appears to be the principal attractant originating from these food lures, as found with *Dacus tryoni* [20, 21]. This study focused on seeking a trap and lure combination that will be appropriate as both a sensitive trapping system for monitoring low numbers of fruit flies and as a control option in bait stations. Traps baited with the 3 component food-based synthetic attractant (Ammonium Acetate, Putrescine and Trimethylamine) showed remarkable performance in tests conducted in Guatemala (Heath et al., 1997). The female selectivity of the synthetic attractant observed will be of considerable value in SIT programmes by removing feral females without eliminating sterile males. Such a trapping system, if used on a large scale during the envisaged SIT programme against *B. zonata* in Mauritius will no doubt enhance its success.

5. CONCLUSIONS

The synthetic food attractants appear to be a more effective and selective option for fruit fly surveillance including *B. zonata*, *B. cucurbitae*, *Ceratitis rosa* and *C. capitata*, than the more conventional hydrolysate protein NuLure and the Torula yeast.

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FIELD COMPARISON OF FOOD-BASED SYNTHETIC ATTRACTANTS AND TRAPS FOR AFRICAN TEPHRITID FRUIT FLIES

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Abstract

Four field trials were conducted on coffee orchards in Ruiru, Central Province, Kenya to compare captures of the Mediterranean fruit fly, *Ceratitis capitata* (Diptera: Tephritidae) in Multilure Plastic McPhail type traps and Israeli Shabtiely traps baited with female selective food-based attractants. In trial 1, wet Ammonium Acetate (AA) + Trimethylamine (TMA) + Putrescine (PT), AA+TMA and TMA+PT captured significantly more female flies than the other treatments. In the second trial, both the wet and dry AA+TMA+PT and wet AA+TMA were superior to the other treatments in capturing females. Among the different synthetic food attractants, female *C. capitata* accounted for 67 to 72% of the total captures while 72 to 74% females were captured using NuLure as attractant in both trials. In trials 3 and 4, treatments containing half patch of AA were equally effective as those treatments containing full patch of AA and in trial 4, both treatments with half patch of AA captured significantly more female *C. capitata* than the NuLure treatment. In trial 3, all treatments in Multilure traps were selective for female *C. capitata* with percent female caught ranging from 62-67% across the different treatments while in trial 4, all treatments caught between 56 to 70% female flies. In all the trials, the different treatments generally captured lower number of males compared with female catches. Traps baited with the different three component treatments also captured *Ceratitis fasciventris*. Two other field trials were also conducted in mango orchards at Nguruman, Rift Valley Province and at Muhaka, Coast Province to compare catches of *Bactrocera invadens* and *Ceratitis cosyra* in Multilure trap baited with female selective food-based attractants. At Nguruman, treatment AA+TMA+PT captured significantly more females and males of *B. invadens* compared with the other treatments while at Muhaka, the NuLure treatment caught more males and females of *B. invadens* although catches were not significantly different from the AA+TMA+PT treatment. For *C. cosyra*, the NuLure, however, caught significantly more females compared with the other treatments in the two trials. Similarly, the NuLure captured more male *C. cosyra* than other treatments at Nguruman but at Muhaka no difference was found among treatments. Results demonstrates for the first time the field responses of mango infesting fruit flies such as *C. fasciventris, C. cosyra* and *B. invadens* to odours of synthetic food attractants and possibility of using the AA+TMA+PT (Biolure) or AA+TMA with full or reduce doses of AA for monitoring of these fruit flies. All treatments captured non-target insects with dipterans and ants predominating in all the trials. Overall, these potent synthetic food attractants offers a new facet in fruit fly detection and monitoring in Africa and possibly suppression through mass trapping.

Key words: *Ceratitis capitata, Ceratitis fasciventris*, *Ceratitis cosyra, Bactrocera invadens,* non-target insects, synthetic attractants, trapping

1. INTRODUCTION

The Medfly, *Ceratitis capitata* (Wiedemann) is a serious pest of several cultivated fruits worldwide [1]. Female flies oviposit in ripening and ripe fruits which are destroyed by larval feeding. Detection and monitoring of this pest has relied on the use of aqueous solution of corn hydrolysate (NuLure) using McPhail traps for females and males [2] and Trimedlure, tert-butyl 4 (and 5)-chloro-2-methylcyclo-hexane-1-carboxylate using Jackson trap for males only [3]. Traps baited with NuLure also capture numerous other fruit flies in addition to *C. capitata*. Although, the male targeted trapping systems are often preferred for detection and monitoring because of their longer range attractivity and specificity [4], their possible use for male annihilation technique that utilizes large numbers of male-attractant traps have not been successful for *C. capitata* without the use of other control methods [5].

The sterile insect technique (SIT), a control method employed for area wide population suppression of medfly requires the use of a female-targeted system that would capture large number of wild females and few sterile and wild males. At present, the use of liquid bait is limited by reduced selectivity, the need for weekly renewal, variation in pH of the solution, which affects efficacy [6-7] and logistical problems associated with deployment. Recent efforts have therefore concentrated on the development of a potent and selective attractant and trapping systems for *C. capitata* females for use in population monitoring, mass trapping and SIT. To this end, a food-based synthetic attractant that, uses Ammonium Acetate (AA) + Trimethylamine (TMA) + Putrescine (PT) were tested and found to be synergistic in capturing pest fruit flies that are attracted to liquid protein-baited traps [8]. Field trials have been conducted in seven countries (Greece, Honduras, Mauritius, Morocco, Portugal, Spain and Turkey) mostly in citrus orchards and traps baited with the three component attractant were found to capture equal or greater numbers of female *C. capitata* than McPhail-type traps baited with NuLure/borax solution and Frutect traps in 10 of the 11 tests conducted in the different countries [9]. No studies have been conducted in any sub-Saharan African country to test the efficacy of this attractant to *C. capitata*. The present investigation which forms part of an FAO and IAEA Co-ordinated Research Programme evaluated the response of *C. capitata* and *C. fasciventris* (Bezzi) (which co-exist with *C. capitata* on coffee) to varying combinations of the three component attractant on coffee. Results are also presented on the response of *C. cosyra* (Walker) and a new invasive species *Bactrocera invadens* Drew Tsuruta & White to the tested synthetic lure on mango.

2. MATERIALS AND METHODS

2.1. Description of coffee experimental sites

The field trials were conducted in a coffee orchard in Ruiru, Central Province of Kenya. Ruiru is located at 01^0 06'31 S 036^0 57'59 E and at an altitude of 1558 m above sea level. Although the orchard was a well-managed one, no chemical insecticides are applied against insect pests as they are considered of minor importance to the grower. Four trials were conducted on coffee each lasting for eight weeks: trial 1 was conducted from September 3 to October 22, 2002 when *C. capitata* population was at an average of about 60 flies/trap/day (FTD) and trial 2 was from November 19, 2002 to January 7, 2003 when fly population was slightly lower at a density of 50 FTD. Trials 3 and 4 were conducted from February 25, 2004 to April 14, 2004 and July 7, 2004 to August 25, 2004 when fly population was much lower at an average of 9 FTD and 15 FTD, respectively. Temperature and humidity was recorded using a data logger (HOBO Pro Series, Bourne MA). The average maximum and minimum temperature during the experimental period was 9 and 28^0C, 12 and 30^0C 10 and 32^0C, and 8 and 25^0C in trials 1, 2, 3 and 4 respectively. Daily humidity variation ranged from 34 to 86%, 35 to 82%, 40 to 78% and 42 to 91% in trials 1, 2, 3 and 4, respectively. Prevailing wind direction was north to east.

2.2. Description of mango experimental sites

Two trials were carried out on mango. The first was at Nguruman, Kajiado District, Rift Valley Province from December 4, 2004 to January 30, 2005. Nguruman is an irrigation scheme located at latitude 01o 54' 44 S, longitude 36o 17' 15 E and altitude of 700 m. The mango growing area is supplied, in addition to rains, with underground irrigation water from three rivers (Oloibortoto, Entasopia and Sampu), which cut across the area eventually discharging into Lake Natron of Tanzania. This area is also surrounded by a dry savannah belt making it an ecological island. The average maximum and minimum temperature during the experimental period was 210C and 350C; minimum RH was 33% and maximum was 76%. The second trial was at Muhaka, Kwale District, Coast Province from January 26 to March 24, 2005. Muhaka is located at latitude 3o 24' 24 S, longitude 38o 21' 25 E and altitude of 60 m above sea level. The average maximum and minimum temperature during the experimental period was 240C and 340C; minimum RH was 42% and maximum was 84%.

2.3. Traps and treatments on coffee

The Multilure Plastic McPhail type trap (MLT) – (Better World Manufacturing, Fresno, CA) was the only trap used in trials 1 and 2. Six treatments were applied in these trials: (1) Liquid protein bait consisting of 300 ml aqueous solution of 9% NuLure and 3% borax, (2) AA+TMA+PT as wet trap containing 270ml of water and 0.01% Triton X-100 (Union Carbide, Danbury, CT) as wetting agent, (3) AA+TMA as wet trap containing water and Triton as above, (4) AA as wet trap plus water and Triton as above, (5) AA+PT as wet trap containing water and Triton as above and (6) AA+TMA+PT as dry trap containing white insert coated with sticky insect adhesive (Tangle Trap, Tanglefoot, Grand Rapids, MI) to retain attracted flies and dimethyl 2,2-diclorovinyl phosphate (DDVP, 5 x 15 x 25mm plug, 10% ai; AgriSense, South Wirral, England) as insecticide. PT, TMA and AA are commercially available as Biolure® (SUTERRA, Bend, OR). In trials 3 and 4, treatment combinations were revised and included: (1) Liquid protein bait consisting of 300ml aqueous solution of 9% NuLure and 3% borax in Multilure trap, (2) AA+TMA+PT as wet trap containing 270ml of water and 0.01% Triton X-100 in Multilure trap, (3) AA + TMA as wet trap containing water and Triton as above in Multilure trap, (4) ½AA + TMA as wet trap containing water and Triton as above in Multilure trap, (5) ½AA+TMA+PT as wet trap containing water and Triton in Multilure trap and (6) AA+TMA+PT as dry trap in Israeli Shabtiely trap.

2.4. Trap and treatments on mango

MLT traps were used in both experiments at Nguruman and Muhaka. Six treatments were applied in these trials: (1) Liquid protein bait consisting of 300ml aqueous solution of 9% NuLure and 3% borax, (2) AA+TMA+PT as wet trap containing 270 ml of water and 0.01% Triton X-100, (3) two patches of AA (2AA) as wet trap plus water and Triton as above, (4) 2AA+TMA as wet trap containing water and Triton as above, (5) 2AA+PT as wet trap plus water and Triton as above and (6) AA+TMA as wet trap plus water and Triton as above.

2.5. Design and evaluation

On coffee and mango the experiments were laid down in a randomized complete block design with five replicated blocks. Distance between blocks and traps within blocks was 15m and 30m, respectively. Placement of traps within blocks was random and traps were rotated sequentially after each sampling. Traps were placed on trees at about 1.5-2m above ground and were checked once a week. The NuLure was renewed every 7 days. All three component bait treatments and DDVP were replaced every four weeks. At each check, the number and sex of fruit flies captured and the number of other insects captured was recorded.

2.6. Statistical analysis

The numbers of fruit flies captured were transformed using log (x +1) to normalize the variance before subjecting the data to analysis of variance. The interaction between treatment and time on trapping efficiency was tested using a factorial model with repeated measures analysis with PROC GLM. Mean female, male, total (male and female) and percent (%) female captured in each block was averaged over the sampling weeks and used for treatment comparison [9] using PROC GLIM and means were separated using Tukey (HSD) test (P=0.05). Transformation of data could not normalize the number of non-target insects captured; as a result Kruskal-Wallis non-parametric analysis was applied to this set of data. All analyses were performed using the SAS [10] software package.

3. RESULTS

3.1. Experiment on coffee

Significant interaction between treatments and time was observed in all trials for female *C. capitata* captured: trial 1 (F=3.43; df=35, 189; P=0.0001), trial 2 (F=2.14; df=35, 192; P=0.0006), trial 3 (F=2.06; df=35, 184; P=0.011), trial 4 (F=2.58; df=35, 184; P=0.0001). Treatments consisting of wet three (AA+TMA+PT) and two component attractants (AA+TMA) and (AA+PT) captured significantly more *C. capitata* females in trial 1 compared with the other treatments (Table I). In the same experiment, *C. fasciventris* was also more attracted to odours of AA+TMA+PT and AA+TMA than to odours arising from the other treatment (Table 2). In both species of fruit flies, the NuLure and AA treatments caught the lowest number of flies in trial 1 (Tables I and II). In trial 2, the dry and wet AA+TMA+PT and wet AA+TMA and AA+PT captured significantly more female *C. capitata* than the other treatments (Table I). However, in *C. fasciventris* females, apart from treatment AA, catches in all other treatments were equal (Table II).

In trials 3 and 4, treatments containing half patch of AA (½AA+TMA and ½AA+TMA+PT) were equally effective as those treatments containing full patches of AA (AA+TMA+PT and AA+TMA) (Table I) in capturing *C. capitata* female and in the fourth experiment, *C. capitata* females were significantly more attracted to odours of treatments containing half patches of AA than the NuLure treatment (Table I). In *C. fasciventris*, treatments consisting of AA+TMA+PT and ½AA+TMA+PT were generally more superior to the other treatments in capturing female flies (Table II).

In *C. capitata*, as expected all attractants generally captured fewer males compared with males. However, the trend in the response to odours from the different treatment was similar to female Captures in all the trials in that AA+TMA+PT, AA+TMA and AA+PT captured significantly more *C. capitata* males than the other treatments (Table I). In the second trial, the wet and dry AA+TMA+PT and AA+TMA caught the highest number of *C. capitata* males (Table 1) while the NuLure and AA treatments captured the lowest number. Treatments wet AA+TMA+PT and AA+TMA were superior to other treatments in capturing male *C. fasciventris* in trial 1 (Table II). *C. fasciventris* males responded more to wet and dry AA+TMA+PT compared with the other treatments (Table II). In trial 3, there was no significant difference in male *C. capitata* captured among treatments in Multilure traps; the Israeli trap, however, captured the lowest number of males. In trial 4, the NuLure treatment and tri-component attractants in Israeli trap recorded the lowest number of male *C. capitata* flies while treatments AA+TMA+PT, ½ AA+TMA+PT and ½AA+TMA captured more male *C. fasciventris* than the other treatments (Table I and II).

Total (male and female) number of *C. capitata* captured in trial 1 was highest in AA+TMA+PT, TMA and AA+PT and was 2.6 to 3.1 times greater than Captures in NuLure (Table I) and total *C. fasciventris* caught in the most effective treatments (AA+TMA+PT and AA+TMA) was 2.6 to 3.4 times greater than catches in NuLure in the same experiment (Table II). In trial 2, comparison of total *C. capitata* captured among all treatments indicated that the wet and dry three component attractants and AA+TMA caught significantly more flies than the other treatments (Table I). The number of flies caught in these treatments was 2.3 to 2.5 times greater than in NuLure. Total catches in *C. fasciventris* was higher in the same treatment as in *C. capitata* plus TMA+AA and the numbers were 1.4 to 1.9 times higher than in NuLure (Table II). In trial 3, total catches in *C. capitata* was significantly higher in all treatments in Multilure trap than in Israeli trap baited with treatment AA+TMA+PT. Total catches were 11-13 times higher in treatments in Multilure trap than in treatment in Israeli trap. (Table I). In *C. fasciventris*, more flies responded to Multilure traps baited with AA+TMA+ than in the NuLure treatmet in trials 3 and 4 (Table II).

All treatments in trials 1 and 2 were selective for females of *C. capitata* and percent female caught ranged from 67 to 72% in trial 1 and 67 to 74% in trial 2 (Table I). For *C. fasciventris*, all attractants were also marginally selective for females ranging from 52 to 62% in trial 1 and slightly higher in trial 2 ranging from 62 to 67% across the various treatments (Table II). In trial 3, all treatments in Multilure traps were selective for female *C. capitata* with percent female caught ranging from 68-71% (Table I) while in trial 4, all treatments caught between 56 to 70% female (Table I). For *C. fasciventris*, treatments in trial 3 were mildly selective in Multilure traps ranging from 52 to 67% (Table II). Only treatments containing half patch of AA were slightly selective for female *C. fasciventris* achieving 55% of female catches in the fourth experiment (Table II).

3.2. Experiment on mango

Significant interaction between treatments and time was observed for female *B. invadens* at Nguruman ($F=1.53$; $df=90,360$; $P=0.0035$) and Muhaka ($F=3.41$; $df=90,360$; $P=0.0001$). At Nguruman, treatment AA+TMA+PT significantly attracted more female and male *B. invadens* compared with other treatments and treatment 2AA captured the lowest number of flies of both sexes (Table III). Total (female and male) was also highest in AA+TMA+PT compared with the other treatments and was 1.5

times higher than catches in the NuLure (Table III). Percent female *B. invadens* ranged from 45 to 50% and did not differ significantly among treatment (Table III). For *C. cosyra*, the NuLure captured significantly more female and male flies when compared with the other treatments and total (male and female) followed a similar trend (Table IV).

At Muhaka, significant differences were observed among treatments with the NuLure treatment capturing more male and female *B. invadens* although this did not differ significantly from the AA+TMA+PT treatments (Table III). Percent female *B. invadens* was highest in the Nulure treatment accounting for 68% of the total flies captured. The NuLure also captured more female *C. cosyra* than other treatments but no significant difference was detected among treatments in male *C. cosyra* (Table IV).

3.3. Non-target insects

Predominant non-target insects captured at Ruiru, Nguruman and Muhaka is presented in Table V. All treatments captured non-targets mostly Dipterans and ants of various families. At Muhaka all treatments consisting of the tri-component bait captured between 4 to 11 times fewer non-targets than the NuLure (Table V).

4. DISCUSSION

Africa is the aboriginal home of *C. capitata, C. fasciventris* and *C. cosyra* in addition to a variety of other fruit flies that causes enormous damage to fruits and vegetables [11, 17]. The damage cause by these flies has been further exacerbated by the arrival of a species of *Bactrocera* of Asian origin recently described as *B. invadens* [12]. *Ceratitis capitata* is especially a worldwide pest of agriculture attacking over 300 different hosts [1] and the need to develop and improve methods for detection, monitoring and suppression continues to receive strong impetus. The results presented herein represent the first evaluation of the three component attractant (AA+TMA+PT) commercially know as Biolure against this pest in its home of origin and responses of other native and invasive species to the tri-component bait. On coffee both 2 (AA+TMA) and three (AA+TMA+PT) component attractants in Multilure traps were very effective in capturing female *C. capitata* while the NuLure and AA treatments were the least effective among the treatments in the first two trials. Studies conducted in Greece and Morocco reported that Multilure traps baited with NuLure was the least effective for *C. capitata* females compared with trap baited with AA+TMA+PT [9]. In Spain, Miranda

TABLE I. COMPARISON OF MEAN (± SE) CATCHES OF *CERATITIS CAPITATA* IN FOUR TRIALS IN COFFEE PLANTATION IN KENYA

Trap	Bait treatment	Retention	Females	Males	Total	% females
Trial 1						
MLT	NuLure	H_2O	20.4 ± 5.1c	8.7 ± 2.8c	29.1 ± 7.8c	72.1± 2.5a
MLT	AA+TMA+PT	H_2O/Triton	57.1 ± 10.4a	26.0± 4.8a	82.9 ± 14.2a	67.0 ± 4.3b
MLT	AA+TMA	H_2O/Triton	58.8 ± 15.2a	31.1 ± 12.1a	89.8 ± 26.6a	67.0 ± 5.1b
MLT	AA	H_2O/Triton	26.9 ± 7.9bc	13.0 ± 6.1bc	39.9 ± 13.8bc	68.9 ± 5.5ab
MLT	TMA+PT	H_2O/Triton	50.8 ± 15.4a	24.4 ± 12.4a	75.2 ± 27.5a	70.5 ± 3.4ab
MLT	AA+TMA+PT	Sticky insert	32.8 ± 9.2b	14.5 ± 6.6b	49.8 ± 18.6b	72.3 ± 2.7a
$F_{[DF=5,184]}$			33.61	31.59	36.19	4.36
P			0.0001	0.0001	0.0001	0.0009
Trial 2						
MLT	NuLure	H_2O	18.3 ± 4.4d	7.2 ± 2.3c	25.5 ± 6.4c	74.3 ± 3.4a
MLT	AA+TMA+PT	H_2O/Triton	39.9 ± 10.7ab	22.9 ± 10.2a	57.9 ± 19.4a	67.4 ± 3.11b
MLT	AA+TMA	H_2O/Triton	37.4 ± 11.5ab	20.5 ± 10.6a	58.0 ± 21.7a	68.6 ± 3.7b
MLT	AA	H_2O/Triton	24.6 ± 7.8cd	11.2 ± 5.2bc	35.8 ± 12.6bc	70.5 ± 2.8b
MLT	PT+TMA	H_2O/Triton	33.6 ± 9.1bc	16.5 ± 7.8ab	50.2 ± 16.1ab	70.7 ± 4.1ab
MLT	AA+TMA+PT	Sticky insert	44.1 ± 12.0a	21.1 ± 8.8a	64.8 ± 20.6a	70.9 ± 3.8ab
$F_{[DF=5,192]}$			14.98	18.53	16.41	6.75
P			0.0001	0.0001	0.0001	0.0001

TABLE I CONTINUES. COMPARISON OF MEAN (± SE) CATCHES OF *CERATITIS CAPITATA* IN FOUR TRIALS IN COFFEE PLANTATION IN KENYA

Trap	Bait treatment	Retention	Females	Males	Total	% females
Trial 3						
MLT	NuLure	H_2O	8.3 ± 2.5ab	4.1 ± 1.6a	12.4 ± 4.0a	68.5 ± 2.8a
MLT	AA+TMA+PT	H_2O/Triton	9.7 ± 1.2a	4.5 ± 1.2a	14.2 ± 2.5a	70.8 ± 3.8a
MLT	AA+TMA	H_2O/Triton	8.0 ± 1.6b	3.8 ± 1.1a	11.8 ± 2.7a	69.8 ± 3.0a
MLT	½AA+TMA	H_2O/Triton	8.6 ± 1.8a	4.2 ± 1.3a	12.8 ± 3.0a	70.1 ± 3.6a
MLT	½AA+TMA+PT	H_2O/Triton	8.6 ± 1.7a	4.6 ± 1.3a	13.2 ± 2.9a	68.4 ± 3.4a
Israeli	AA+TMA+PT	None	0.7 ± 0.6c	0.4 ± 0.3b	1.1 ± 0.9b	29.3 ± 5.9b
$F_{[DF=5,188]}$			87.96	49.58	98.74	31.97
P			0.0001	0.0001	0.0001	0.0001
Trial 4						
MLT	NuLure	H_2O	5.8 ± 2.2b	2.8 ± 0.9b	8.2 ± 3.0b	68.2 ± 2.7a
MLT	AA+TMA+PT	H_2O/Triton	15.0 ± 3.2a	6.6 ± 1.2a	22.0 ± 4.1a	69.7 ± 2.1a
MLT	AA+TMA	H_2O/Triton	12.9 ± 2.3a	5.9 ± 1.46a	18.9 ± 3.8a	69.7 ± 2.8a
MLT	½AA+TMA	H_2O/Triton	13.6 ± 3.0a	6.5 ± 1.5a	20.2 ± 4.6a	68.1 ± 2.7a
MLT	½AA+TMA+PT	H_2O/Triton	13.2 ± 1.9a	5.5 ± 0.6a	18.9 ± 2.4a	69.9 ± 1.9a
Israeli	AA+TMA+PT	None	2.4 ± 1.3c	1.2 ± 0.5c	3.5 ± 1.8c	56.4 ± 5.5a
$F_{[DF=5,188]}$			105.75	51.71	108.71	5.83
P			0.0001	0.0001	0.0001	0.0001

Average number of flies is given as flies/trap/day. Means within a column followed by the same letter do not differ significantly by Tukey (HSD) test (P=0.05). MLT = Multilure Plastic McPhail Trap; PT = Putrescine; TMA = Trimethylamine; AA = Ammonium acetate; H_2O = Water.

TABLE II. COMPARISON OF MEAN (± SE) CATCHES OF *CERATITIS FASCIVENTRIS* IN FOUR TRIALS IN COFFEE PLANTATION IN KENYA

Trap	Bait treatment	Retention	Females	Males	Total	% females
Trial 1						
MLT	NuLure	H_2O	2.8 ± 0.8c	2.2 ± 0.5c	5.1 ± 1.2c	52.4 ± 3.5b
MLT	AA+TMA+PT	H_2O/Triton	9.0 ± 2.24a	6.9 ± 1.5a	17.3 ± 3.8a	56.5 ± 3.1a
MLT	AA+TMA	H_2O/Triton	7.2 ± 1.1a	5.9 ± 1.1a	13.1 ± 2.1a	56.6 ± 3.4a
MLT	AA	H_2O/Triton	2.4 ± 0.4c	1.7 ± 0.5c	4.0 ± 0.9c	62.0 ± 3.6a
MLT	TMA+AA	H_2O/Triton	5.3 ± 1.2b	4.2 ± 0.9b	9.5 ± 2.0b	55.5 ± 3.6a
MLT	AA+TMA+PT	Sticky insert	4.7 ± 0.8b	3.7 ± 0.8b	8.3 ± 1.5b	57.8 ± 2.7a
$F_{[DF=5,184]}$			46.47	40.68	47.52	2.52
P			0.0001	0.0001	0.0001	0.0309
Trial 2						
MLT	NuLure	H_2O	5.1 ± 1.3ab	2.9 ± 0.7cd	8.0 ± 1.9bc	64.5 ± 3.3ab
MLT	AA+TMA+PT	H_2O/Triton	8.6 ± 1.5a	4.8 ± 1.3ab	14.4 ± 2.9a	65.1 ± 2.5ab
MLT	AA+TMA	H_2O/Triton	7.2 ± 1.5ab	4.2 ± 1.6bc	11.4 ± 3.0ab	66.5 ± 3.8a
MLT	AA	H_2O/Triton	4.7 ± 1.6c	2.2 ± 0.8d	6.2 ± 1.8c	67.0 ± 2.5a
MLT	TMA+AA	H_2O/Triton	7.4 ± 1.6ab	4.1 ± 1.2bc	11.5 ± 2.7ab	65.9 ± 3.5a
MLT	AA+TMA+PT	Sticky insert	9.1 ± 1.7a	6.1 ± 1.4a	15.3 ± 2.9a	61.7 ± 2.5b
$F_{[DF=5,192]}$			15.21	17.88	16.52	3.22
P			0.0001	0.0001	0.0001	0.0082

TABLEII (CONTINUES). COMPARISON OF MEAN (± SE) CATCHES OF *CERATITIS FASCIVENTRIS* IN FOUR TRIALS IN COFFEE PLANTATION IN KENYA

Trap	**Bait treatment**	**Retention**	**Females**	**Males**	**Total**	**% females**
Trial 3						
MLT	NuLure	H_2O	0.6 ± 0.2c	0.3 ± 0.1ab	0.8 ± 0.3b	60.8 ± 4.9a
MLT	AA+TMA+PT	H_2O/Triton	1.5 ± 0.4a	0.7 ± 0.3a	2.3 ± 0.6a	67.1 ± 4.0a
MLT	AA+TMA	H_2O/Triton	0.7 ± 0.1c	0.3 ± 0.1bc	1.0 ± 0.2b	60.6 ± 4.6a
MLT	½AA+TMA	H_2O/Triton	0.9 ± 0.3bc	0.4 ± 0.1ab	1.3 ± 0.5b	67.3 ± 4.6a
MLT	½AA +PT+ TMA	H_2O/Triton	1.2 ± 0.3ab	0.6 ± 0.1a	1.8 ± 0.4a	52.4 ± 4.9a
Israeli	AA+TMA+PT	None	0.1 ± 0.1d	0.1 ± 0.1d	0.2 ± 0.1c	21.7 ± 5.3b
$F_{[DF=5,188]}$			29.10	17.20	33.62	18.74
P			0.0001	0.0001	0.0001	0.0001
Trial 4						
MLT	NuLure	H_2O	0.3 ± 0.1c	0.3 ± 0.1c	8.0 ± 1.9bc	42.6 ± 5.6ab
MLT	AA+TMA+PT	H_2O/Triton	1.4 ± 0.3a	1.2 ± 0.1a	14.4 ± 2.9a	50.9 ± 2.7a
MLT	AA+TMA	H_2O/Triton	0.9 ± 0.2ab	0.9 ± 0.2ab	11.4 ± 3.0ab	50.0 ± 4.7a
MLT	½AA+TMA	H_2O/Triton	1.0 ± 0.2a	0.9 ± 0.2ab	6.2 ± 1.8c	55.4 ± 2.6a
MLT	½AA+TMA+PT	H_2O/Triton	1.2 ± 0.2a	1.0 ± 0.2ab	11.5 ± 2.7ab	55.3 ± 4.4a
Israeli	AA+TMA+PT	None	0.7 ± 0.3b	0.4 ± 0.2c	15.3 ± 2.9a	34.3 ± 5.5b
$F_{[DF=5,188]}$			20.68	23.71	16.52	8.88
P			0.0001	0.0001	0.0001	0.0001

Average number of flies is given as flies/trap/day. Means within a column followed by the same letter do not differ significantly by Tukey (HSD) test (P=0.05). MLT = Multilure Plastic McPhail Trap; PT = Putrescine; TMA = Trimethylamine; AA = Ammonium Acetate; H_2O = Water.

et al. [13] showed in one experiment that Multilure traps baited with NuLure captured more *C. capitata* females than wet or dry trap baited with AA+TMA+PT. In another experiment the authors demonstrated that catches in both treatments were equal.

When treatment combinations were revised in trials 3 and 4 with the aim of reducing high doses of AA, it was observed that treatments containing half patch of AA were generally as effective as those treatments containing full patch of the ammonium salt in attracting *C. capitata* on coffee. The results suggest that the use of high concentrations of AA in combination with PT+TMA or with TMA may not always be necessary to achieve effective results. Addition of PT also does not seem to enhance efficacy because catches in the treatments containing this compound in most cases did not differ significantly from treatment combinations without PT. However, the use or omission of any of the component will depend on the intent of the operation e.g. if trapping is aimed at monitoring or suppression, PT may be omitted from the tri-component attractant but if detection is the main objective sensitivity is required and PT may be added to the combination.

The Israeli Shabtiely trap generally performed poorly in the experiments when compared with the Multilure trap. Trap performance can be affected by its design because this influences odour emissions. This trap is designed to kill flies by suffocation. Minute laterals holes on the trap may probably have limited odour emission from this trap thus adversely affecting insect attraction. This trap was also too bulky and handling and servicing was rather time consuming.

Female selectivity for *C. capitata* observed in the present investigation is within the range reported with these food-based synthetic attractants. In Israel, Multilure traps baited with the three component attractant (Biolure) captured 2 times more *C. capitata* females than males in a citrus orchard [14]. In addition to the high attractivity, Katsoyannos et al. [15] noted that traps baited with 2 component attractant or Biolure were more female selective capturing 2 to 5 times more female *C. capitata* than males. In a larger field trials conducted in the seven countries listed earlier to compare Captures of *C. capitata* among several types of traps baited with two or three components of Biolure, Epsky et al. [9] however observed that variation in female selectivity could range from 43 to 90% of the total fly capture.

In the first trial on coffee, the wet Biolure treatments in Multilure trap were generally more efficacious in capturing flies than the dry treatment but in the second experiment, the dry treatment was as equally effective as the wet ones. Katsoyannos et al. [16] compared the three component Biolure as wet and dry trap in Multilure and Tephri traps and observed that wet traps in Multilure trap were the most attractive for both males and female of *C. capitata*. Explanation to the increased efficacy of the dry treatment in trial 2 is presently elusive but would suggest that water may not be particularly critical at all environmental conditions for a synergistic effect of the three components in Multilure trap. Although we did not evaluate Tephri trap in our experiments, contrary to the results of Katsoyannos and co-workers, the use of the three component attractants in Tephri traps as dry lure were found to be more efficacious than wet trap baited with same lure in Spain [13]. Dry traps are much easier to service than wet ones since they do not require the addition of water. The use of Biolure in dry traps should therefore not be completely discarded, as they may be considered more practical for mass trapping under certain environmental conditions than wet traps.

In addition to the already confirmed efficacy of Biolure for capturing *C. capitata*, our results demonstrates for the first time the field responses of mango infesting fruit flies such as *C. fasciventris, C. cosyra* and *B. invadens* to odours of Biolure and possibility of using the AA+TMA+PT or AA+TMA with full or reduce doses of AA for monitoring and or suppression of the flies. A few *Trirhithrum* sp., *Dacus* sp. and *Ceratitis* sp. were also captured in all trials. *Ceratitis fasciventris* is a highly polyphagous species that have been recorded from a broad range of cultivated fruits [17]. During an extensive survey conducted by African Fruit Fly Initiative, *C. fasciventris* (together with its close relative, *Ceratitis rosa* Karsh) was ranked second in terms of economic importance on mango after *C. cosyra* [11]. In areas where it co-exists with *C. capitata*, it has been reported to be capable of displacing it from several hosts [18]. Given that this pest is highly tolerant to a broad range of temperatures and seem capable to establishing in cooler areas than *C. capitata*, it is of major quarantine concern in Europe and America. *B. invadens* on the other hand was first detected in the Kenyan Coast in March 2003 and ever since this first report has spread across several east and west African countries [12]. Yield losses on mango have been estimated to range between 20-80% depending on the locale (Ekesi et al., unpublished data). The Inter-African Phytosanitary council has rated this pest as "a devastating quarantine pest." (www.iaea.org/programmes/nafa/d4/public/d4_pbl_i7.html [Insect Pest Control Newsletter No. 65]). Eradication through male annihilation technology is often considered as the sine qua non for fruit flies within the *B. dorsalis* group [19-20]. However the high economic cost, vast reservoirs, poor quarantine setting and insufficient donor support due to low profits from the horticulture industry suggest that eradication of this pest may be a difficult task under the African setting. Generally, percent female catches of *B. invadens* did not exceed 50% at Nguruman but marginally high at Muhaka. However, the fact that this pest and all the fruit fly species mentioned above respond to Biolure suggests that the attractant could be employed for their management. Dry McPhail type trap baited with Biolure were effective in suppressing *C. capitata* through perimeter trapping in pear, plum and persimmon but with several limitation such as cost-effectiveness [21].

All the treatments captured non-target insects which included ants and Dipterans as the predominant group. Some Lepidopterans, Hymenopterans, Coleopterans and spiders were also caught but at very negligible numbers. These groups of non-targets have typically been reported in traps baited with liquid protein bait and Biolure [9, 22]. Ants appeared to be attracted to trapped flies as they were commonly observed predating on flies. Dipterans which were mainly Sarcophagids appeared to be attracted to odours of decomposing flies in the wet traps especially when high numbers of flies are captured in the traps. Some treatments containing components of Biolure captured more non-targets than the NuLure (Table 5) and this contrast with previous investigations that reported that two or three components Biolure attractants caught significantly less number of non-targets compared with NuLure in Mediterranean region [13, 16]. The discrepancies could among others be attributed to variation in biodiversity within countries and regions.

5. CONCLUSION

The results of the present investigation carried out under moderate to high populations of the *C. capitata* demonstrates that Multilure trap baited with AA+TMA+PT and AA+TMA captured more females than male flies compared with other treatment combinations. It also showed that reduce doses of AA could also be used to achieve the same efficacy. The observation that *C. fasciventris, C. cosyra* and *B. invadens* all of which are economic pests of mango responds to different combinations of the synthetic attractant is considered significant. Preliminary field cage observation indicates that other important African fruit flies species of quarantine importance also respond to these lures (A. Manrakhan et al., unpublished data) but there is the need to test the efficacy under field conditions. Overall, this potent synthetic attractant offers a new facet in fruit fly detection and monitoring and possibly suppression through mass trapping.

TABLE III. COMPARISON OF MEAN (± SE) CATCHES OF *BACTROCERA* SP. AT TWO LOCATIONS IN MANGO ORCHARD IN KENYA

Trap	**Bait treatment**	**Retention**	**Females**	**Males**	**Total**	**% females**
Nguruman						
MLT	NuLure	H_2O	14.4 ± 5.1b	14.9 ± 5.9b	29.3 ± 11.0b	46.1 ± 2.3a
MLT	AA+TMA+PT	H_2O/Triton	21.5 ± 8.1a	23.9 ± 10.0a	44.8 ± 18.2a	49.8 ± 2.0a
MLT	2AA	H_2O/Triton	8.6 ± 3.7c	10.7 ± 5.1c	19.3 ± 8.8c	45.1 ± 1.9a
MLT	2AA+TMA	H_2O/Triton	14.3 ± 5.1b	16.1 ± 6.8b	30.4 ± 11.8ab	48.4 ± 2.1a
MLT	2AA+PT	H_2O/Triton	12.4 ± 5.4b	15.1 ± 7.3b	27.5 ± 12.7b	46.0 ± 2.4a
MLT	AA+TMA	H_2O/Triton	15.9 ± 6.1b	17.9 ± 7.5b	33.7 ± 13.7b	47.1 ± 2.3a
$F_{[DF=5,456]}$			18.10	14.68	16.45	1.97
P			0.0001	0.0001	0.0001	0.0819
Muhaka						
MLT	NuLure	H_2O	7.3 ± 4.5a	4.3 ± 2.9a	11.6 ± 7.3a	67.5 ± 2.1a
MLT	AA+TMA+PT	H_2O/Triton	5.6 ± 1.3ab	4.1 ± 1.1ab	9.2 ± 2.3ab	59.6 ± 1.7bc
MLT	2AA	H_2O/Triton	2.2 ± 0.6c	1.3 ± 0.4d	3.4 ± 0.9d	65.5 ± 2.1ab
MLT	2AA+TMA	H_2O/Triton	3.9 ± 0.9bc	3.2 ± 0.9abc	7.1 ± 1.7bc	59.2 ± 1.6bc
MLT	2AA+PT	H_2O/Triton	3.5 ± 0.8c	2.5 ± 0.6cd	6.1 ± 1.3cd	57.7 ± 1.8c
MLT	AA+TMA	H_2O/Triton	3.8 ± 1.4bc	2.8 ± 0.9bc	6.5 ± 2.2bcd	61.2 ± 2.2bc
$F_{[DF=5,456]}$			14.21	10.14	12.76	5.34
P			0.0001	0.0001	0.0001	0.0001

Average number of flies is given as flies/trap/day. Means within a column followed by the same letter do not differ significantly by Tukey (HSD) test (P=0.05). MLT = Multilure Plastic McPhail Trap; PT = Putrescine; TMA = Trimethylamine; AA = Ammonium Acetate; H_2O = Water.

TABLE IV. COMPARISON OF MEAN (± SE) CATCHES OF *CERATITIS COSYRA* AT TWO LOCATIONS IN MANGO ORCHARD IN KENYA

Trap	Bait treatment	Retention	Females	Males	Total
Nguruman					
MLT	NuLure	H_2O	1.53 ± 0.58a	1.09 ± 0.36a	2.62 ± 0.88a
MLT	AA+TMA+PT	H_2O/Triton	0.83 ± 0.40ab	0.44 ± 0.31b	1.29 ± 0.66b
MLT	2AA	H_2O/Triton	0.53 ± 0.31b	0.27 ± 0.21b	0.79 ± 0.43b
MLT	2AA+TMA	H_2O/Triton	0.68 ± 0.38b	0.45 ± 0.20b	1.13 ± 0.53b
MLT	2AA+PT	H_2O/Triton	0.70 ± 0.43b	0.41 ± 0.24b	1.12 ± 0.66b
MLT	AA+TMA	H_2O/Triton	0.82 ± 0.49b	0.42 ± 0.23b	1.25 ± 0.70b
$F_{[DF=5,456]}$			5.29	9.52	8.17
P			0.0001	0.0001	0.0001
Muhaka					
MLT	NuLure	H_2O	0.05 ± 0.05a	0.03 ± 0.04a	0.08 ± 0.07a
MLT	AA+TMA+PT	H_2O/Triton	0.04 ± 0.02ab	0.01 ± 0.01a	0.04 ± 0.02ab
MLT	2AA	H_2O/Triton	0.01 ± 0.01ab	0.01 ± 0.01a	0.01 ± 0.01b
MLT	TMA+2AA	H_2O/Triton	0.04 ± 0.03ab	0.03 ± 0.02a	0.07 ± 0.04a
MLT	2AA+PT	H_2O/Triton	0.01 ± 0.01b	0.01 ± 0.01a	0.01 ± 0.01b
MLT	AA+TMA	H_2O/Triton	0.02 ± 0.01ab	0.01 ± 0.01a	0.04 ± 0.02ab
$F_{[DF=5,456]}$			2.95	1.72	3.33
P			0.0125	0.1295	0.0056

Average number of flies is given as flies/trap/day. Means within a column followed by the same letter do not differ significantly by Tukey (HSD) test (P=0.05). MLT = Multilure Plastic McPhail Trap; PT = Putrescine; TMA = Trimethylamine; AA = Ammonium Acetate; H_2O = Water.

TABLE V. COMPARISON OF MEAN (± SE) CATCHES OF DOMINANT NON-TARGET ORGANISMS IN ALL TRIALS IN COFFEE PLANTATION AND MANGO ORCHARD IN KENYA

Trap	**Bait treatment**	**Retention**	**Dipterans**	**Ants**	**Spiders**
Trial 1 (Coffee)					
MLT	NuLure	H_2O	13.9 ± 2.7	15.5 ± 10.0	0.2 ± 0.1
MLT	AA+TMA+PT	H_2O/Triton	38.8 ± 6.9	9.4 ± 5.3	0.2 ± 0.1
MLT	AA+TMA	H_2O/Triton	28.6 ± 5.2	1.8 ± 0.3	0.2 ± 0.1
MLT	AA	H_2O/Triton	16.0 ± 3.9	1.6 ± 0.6	0.1 ± 0.1
MLT	TMA+AA	H_2O/Triton	25.8 ± 3.6	1.0 ± 0.3	0.7 ± 0.5
MLT	AA+TMA+PT	Sticky insert	3.3 ± 0.7	6.3 ± 4.3	0.3 ± 0.1
χ^2 [DF=5]			34.99	13.67	1.89
P			0.0001	0.0179	0.0.8637
Trial 2 (Coffee)					
MLT	NuLure	H_2O	6.6 ± 1.9	99.1 ± 51.9	0.8 ± 0.5
MLT	AA+TMA+PT	H_2O/Triton	20.5 ± 5.7	132.5 ± 109.9	0.2 ± 0.1
MLT	AA+TMA	H_2O/Triton	13.4 ± 3.4	96.5 ± 44.9	0.2 ± 0.1
MLT	AA	H_2O/Triton	6.1 ± 1.8	69.8 ± 41.7	0.1 ± 0.1
MLT	TMA+AA	H_2O/Triton	12.1 ± 1.8	33.3 ± 25.4	0.2 ± 0.1
MLT	AA+TMA+PT	Sticky insert	4.4 ± 1.4	64.3 ± 36.6	0.3 ± 0.2
χ^2 [DF=5]			18.40	5.14	1.67
P			0.0025	0.3990	0.8926

TABLE V (CONTINUED). COMPARISON OF MEAN (± SE) CATCHES OF DOMINANT NON-TARGET ORGANISMS IN ALL TRIALS IN COFFEE PLANTATION AND MANGO ORCHARD IN KENYA

Trap	Bait treatments	Retention	Dipterans	Ants	Spiders
Trial 3 (Coffee)					
MLT	NuLure	H_2O	10.1 ± 3.6	88.9 ± 35.7	0.6 ± 0.3
MLT	AA+TMA+PT	H_2O/Triton	8.0 ± 3.0	8.4 ± 5.3	0.1 ± 0.1
MLT	AA+TMA	H_2O/Triton	6.2 ± 2.1	3.1 ± 0.8	0.2 ± 0.1
MLT	½AA+TMA	H_2O/Triton	7.5 ± 3.4	9.6 ± 8.7	0.5 ± 0.4
MLT	½AA TMA+PT	H_2O/Triton	5.9 ± 1.5	17.8 ± 9.8	0.5 ± 0.2
Israeli	AA+TMA+PT	None	0.1 ± 0.1	0.7 ± 0.5	0.0 ± 0.0
$\chi^2_{[DF=5]}$			74.94	113.31	18.71
P			0.0001	0.0001	0.0022
Trial 4 (Coffee)					
MLT	NuLure	H_2O	4.2 ± 1.2	19.5 ± 11.2	0.2 ± 0.1
MLT	AA+TMA+PT	H_2O/Triton	4.5 ± 1.4	5.5 ± 3.9	0.1 ± 0.1
MLT	AA+TMA	H_2O/Triton	2.7 ± 0.8	1.4 ± 0.3	0.1 ± 0.1
MLT	½AA+TMA	H_2O/Triton	2.8 ± 1.1	3.4 ± 1.3	0.1 ± 0.1
MLT	½AA+TMA+PT	H_2O/Triton	6.4 ± 1.4	6.9 ± 6.5	0.0 ± 0.0
Israeli	AA+TMA+PT	None	0.1 ± 0.1	0.3 ± 0.3	0.0 ± 0.0
$\chi^2_{[DF=5]}$			85.48	57.02	9.34
P			0.0001	0.0001	0.0964

TABLE V (CONTINUED). COMPARISON OF MEAN (± SE) CATCHES OF DOMINANT NON-TARGET ORGANISMS IN ALL TRIALS IN COFFEE PLANTATION AND MANGO ORCHARD IN KENYA

Treatments			Dipterans	Ants
Nguruman (Mango)				
MLT	NuLure	H_2O	16.5 ± 6.3	4.0 ± 3.0
MLT	AA+TMA+PT	H_2O/Triton	15.8 ± 3.1	1.1 ± 0.9
MLT	2AA	H_2O/Triton	3.1 ± 1.3	1.9 ± 1.0
MLT	2AA+TMA	H_2O/Triton	12.6 ± 4.6	2.3 ± 1.3
MLT	2AA+PT	H_2O/Triton	12.3 ± 5.1	1.4 ± 0.8
MLT	AA+TMA	H_2O/Triton	11.4 ± 2.8	2.2 ± 1.7
$\chi^2_{[DF=5]}$			78.994	13.89
P			0.0001	0.0163
Muhaka (Mango)				
MLT	NuLure	H_2O	10.3 ± 6.1	8.4 ± 5.7
MLT	AA+TMA+PT	H_2O/Triton	1.0 ± 0.4	1.1 ± 1.3
MLT	2AA	H_2O/Triton	1.6 ± 1.1	0.4 ± 0.7
MLT	2AA+TMA	H_2O/Triton	1.3 ± 0.7	0.3 ± 0.3
MLT	2AA+PT	H_2O/Triton	2.8 ± 1.6	0.0 ± 0.0
MLT	AA+TMA	H_2O/Triton	0.9 ± 0.4	0.1 ± 0.2
$\chi^2_{[DF=5]}$			79.65	21.22
P			0.0001	0.0007

MLT = Multilure Plastic McPhail Trap; PT = Putrescine; TMA = Trimethylamine; AA = Ammonium Acetate; H_2O = Water.

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Annex 1

SUMMARY TABLE

List of Treatments that were Evaluated (2000-2004) and Corresponding Result

No.	TRAP	LURE	RETENTION	SUBTROPICAL/TROPICAL													MEDITERRANEAN			TEMPERATE						
				C.c.	C. r.	C.f.	C. co.	C. a.	A.l.	A.o.	A. ser.	A. st.	A. f.	B. z.	B. c.	B. o.	C.c.	B. z.	B. o.	C.c.	A.l.	A.o.	A. ser.	A. st.	A. f.	B. o.
1	MLT	TORULA	WATER	LR	MR				BR	BR	BR	BR	BR	MR	BR					LR	BR	BR	BR	BR		
2	MLT	NULURE	WATER	LR	MR	LR	BR	BR	BR	BR	BR	BR	BR	MR	LR		LR		BR	LR						BR
3	MLT	AA+PT+TMA	WATER/TRITON	BR	BR	BR			LR	LR	LR	LR	LR	BR	BR		BR			BR						
4	MLT	AA+PT+TMA	WATER/PG		LR				LR	LR	LR	LR	LR				LR			LR						
5	MLT	AA+PT+TMA	DDVP		LR												LR			LR						
6	MLT	AA+PT+TMA	DM		LR												BRft			LR						
7	MLT	AA+PT+TMA	STICKY		LR												BRft			LR						
8	MLT	1/2AA+PT+TMA	WATER/TRITON														LR			LR						
9	MLT	AB+PT	WATER/TRITON						LR	LR	LR	LR	LR													
10	MLT	AB	WATER/TRITON												LR				LR							
11	MLT	AB	DDVP												LR				LR							
12	MLT	2AB	WATER/TRITON						LR	LR	LR	LR	LR						LR							
13	MLT	4AB	WATER/TRITON																BRft							
14	MLT	2AB+TMA	WATER/TRITON																LR							
15	MLT	4AB+TMA	WATER/TRITON																LR							
16	MLT	2AB+PT	WATER/TRITON						LR	LR	LR	LR	LR						LR							
17	MLT	4AB+PT	WATER/TRITON																LR							
18	MLT	AB+SK	WATER/TRITON																LR							
19	MLT	AP	WATER/TRITON												LR				LR							
20	MLT	1/2AA	WATER/TRITON						LR	LR	LR	LR	LR	LR	LR											
21	MLT	AA	WATER/TRITON												BR		LR		LR	LR						
22	MLT	2AA	WATER/TRITON											BR												
23	MLT	1/4AA+PT	WATER/TRITON						BR	x	BR	LR	LR							LR						
24	MLT	1/2AA+PT	WATER/TRITON						BR	x	BR	LR	LR							LR						
25	MLT	AA+PT	WATER/TRITON	LR		LR			BR	BR	BR	LR	BR				LR			LR						

26	MLT	2AA+PT	WATER/TRITON						LR	LR	LR	LR	LR							LR						
27	MLT	1/2AB+PT	WATER/TRITON						LR	LR	LR	LR	LR													
28	MLT	2AB+PT	WATER/TRITON						LR	LR	LR	LR	LR													
29	MLT	AA+TMA	WATER/TRITON	BR		BR											BR			BR						
30	MLT	1/2AA+TMA	WATER/TRITON																	LR						
31	MLT	AS	WATER/TRITON											LR	LR				LR							
32	MLT	Di-AP	WATER/TRITON		MR									LR	LR											
33	TEPHRI	AA+PT+TMA	DDVP	Not tested													BR			Not tested						
34	ISRAELI	AA+PT+TMA	NONE	Not tested													BR			Not tested						
35	JK	AA+PT+TMA	STICKY																	LR						

BR

C.c. = C. capitata	A.l. = A. ludens	B.z. = B. zonata
C.r. = C. rosa	A. o. = A. obliqua	B.c. = B. cucurbitae
C. c. = cosyra	A. ser. = A. serpentina	B. o. = B. oleae
C. f. = C. fasiventris	A. st. =n A. striata	
C. a. = anonae	A. f. = A. fraterculus	

LEYEND:

BR	Best response
BRft	Bet response (needs further testing)
MR	Medium response
LR	Low response
(shaded)	Not applicable

OBSERVATIONS:

1. Treatment 1 was the best for *A. obliqua* only in Honduras.
2. Treatment 23 was the best for *A.ludens* only in Honduras, and for *A.serpentina* only Mexico
3. Treatment 24 was the best for *A.ludens* only in Honduras, and for *A.serpentina* only Mexico
4. Treatment 25 was the best for *A.ludens* only in Mexico, for *A.obliqua* only in Costa Rica and Mexico, for *A.serpentina* only in Mexico and for *A.fraterculus* only in Mexico.
5. Treatment 29 was the best for C.r., C. co., C.a. only in lab tests. Not recommended for delimiting trapping and detection for exclusion.

Annex 2

SCIENTIFIC PUBLICATIONS

ALEMANY A., M.A. MIRANDA, D. CASTRO, C. MARTIN ESCORZA. 2004. Computer graphic simulation of Mediterranean fruit fly population density changes in a citrus orchard. *In* B.N. Barnes (Ed.). Proceedings of the 6th International Symposium on Fruit Flies of Economic Importance. Stellenbosch, South Africa. Isteg Scientific Publications, Irene (RSA).pp 61- 65.

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