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WORKING MATERIAL

Development of Bait Stations for Fruit Fly Suppression in Support of SIT

Report and recommendations of the consultants group meeting organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Mazatlán, Mexico, 30 October -1 November 2008

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NOTE

Summary

A more economic and practical fruit fly suppression tool is needed to replace conventional aerial and ground bait sprays applications over human settlements, protected natural areas, and difficult to access areas where fruit fly hosts exist. This has been a major request from area-wide integrated pest management action programmes using the Sterile Insect Technique (SIT) as a component.

In recent years, especially in Europe, most conventional insecticides used to control fruit pests have been banned (e.g. malathion, dichlorvos and other organophosphates), therefore areas producing fruits and vegetables for markets that request low insecticide residues or even fruit and vegetable organic farming is seeking for a more economic fruit fly control option to the spinosad-based bait sprays and to the use of mass trapping.

To address these requests, bait stations can be one of the most suitable alternatives. The development of these devices needs to take into consideration cost-effectiveness, and long lasting attractants and killing agents, and should target female fruit flies. Recent developments of synthetic food attractants and long-lasting formulations open the possibility to improve the existent baits stations or develop new ones.

With this objective the Insect Pest Control Subprogramme of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture organized a Consultants Meeting ("Development of Bait Stations for Fruit Fly Suppression in Support of SIT"), held in Mazatlán, Mexico, from 30 October to 1 November 2008, with the participation of 14 scientists from the Instituto Nacional de Tecnología Agropecuaria, Argentina; Department of Primary Industries and Fisheries, Australia; North American Plant Protection Organization, Canada; African Insect Science for Food & Health, Kenya; Universidad Politécnica de Valencia, Spain; Institut de Recerca i Tecnologia Agroalimentàries, Spain, Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación, Mexico; US Department of Agriculture, USA; and the FAO/IAEA Insect Pest Control Subprogramme, Austria. The main tasks of this Consultants Meeting were a) to review the current state and actual knowledge of fruit fly bait stations, and b) to identify the R&D needs to further develop, evaluate and validate fruit fly bait stations.

Any further development and validation of bait stations will require an area-wide approach in view of fly migration, and evaluation will have to take into account fruit infestation and cost-effectiveness. Additional research is needed to optimize bait stations, like the development of long-lasting attractants and killing agents, the safe use of killing agents, the development of stronger female attractants and improved bait station devices that are ideally biodegradable. In terms of procedures, densities and deployment should be optimized and evaluation must be based on fruit infestation levels. Cost-benefit analysis is a critical component for determining the feasibility of any bait station adoption.

A Task Force was created with coordination by the FAO/IAEA Insect Pest Control Subprogramme, and participation of research institutions, industry, fruit and vegetable producers and action programmes, to further develop the bait station technology for cost-effective fruit fly suppression in the special situations described above.

As an output of the Consultants Meeting, the present document will be distributed to the stakeholders involved in the development, evaluation, production, trade and use of fruit fly bait stations including researchers, industry, fruit and vegetables producers, and action programmes. Stakeholders are expected to contribute by facilitating research and development of bait station technology.

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1. Introduction

A more economic and practical fruit fly suppression tool is needed to replace conventional aerial and ground bait sprays applications over human settlements, protected natural areas, and difficult to access areas where fruit fly hosts exist. This has been a major request from area-wide integrated pest management action programmes using the Sterile Insect Technique (SIT) as a component. Traditional fruit and vegetable export programmes based on fruit fly free areas, areas of fruit fly low prevalence in a systems approach and, phytosanitary post-harvest treatments have also been claiming for an effective fruit fly control alternative to the current insecticide/bait application. Fruit and vegetable organic farming is seeking too for a more economic fruit fly control option to the insecticide-bait currently available and to the use of mass trapping.

To address these requests, bait stations as an “attract and kill” technology can be one of the most suitable alternatives. Due to the lack of a standard bait station commercially available, locally-produced bait stations have been used in action programmes for years; however, there has not been a concerted effort for evaluation of the wide variety of bait stations so that their cost-effectiveness is not really known. In recent years, there has been innovations on attractants and killing compounds, therefore, developing bait stations as an additional fruit fly control option is seen as a feasible task.

On the other hand, the mass trapping of fruit flies may be another system for fruit fly suppression, although its high application cost has limited its use.

1.1. Background

For over sixty years, attractants based on natural protein solutions such as torula yeast and hydrolysed protein has been the main basis for survey and control fruit fly populations. These food-based compounds can attract both female and male. During the last decade, however, the first effective female-biased synthetic food lure for the Mediterranean fruit fly (*Ceratitis capitata*) was developed. This lure is now being used for surveillance purposes in most large-scale control programmes against this pest (FAO/IAEA 1999) worldwide. Also, a new liquid toxic bait is now commercially available which is a combination of a new bait (Sol-Bait) and spinosad, a derivative of a soil microorganism. This new toxic bait has been replacing in many countries the long-time-used combination of malathion-hydrolysed protein for ground and aerial applications.

A Coordination Research Project (CRP) entitled "Development of Improved Attractants and Their Integration into Fruit Fly SIT Management Programmes" was conducted during 2000 – 2005 with emphasis on developing female-biased trapping systems for fruit fly species other than medfly, evaluating mass trapping as a method for population suppression, and developing bait stations for fruit fly control. One of the main recommendations of the CRP was the need to further develop a more cost effective bait stations as a suppression tool for fruit flies (FAO/IAEA, 2007).

In addition to the data produced by the CRP, there are other recent technical breakthroughs that can facilitate this task such as:

- Availability of dry synthetic female attractants for medfly and some species of *Anastrepha* and *Bactrocera*, which are more specific and have better controlled release rate than the liquid attractants.
- More environment-friendly insecticides in view of legal and social constraints to the application of organophosphates/bait combinations.
- Long-lasting bait formulations, active in the field for up to six months.
- Liquid baits that not only attract the fruit flies but also induce consumption of the bait.

1.2 Objectives

The objectives of the Consultants Meeting were:

- to review the status of development of a variety of bait stations;
- to assess the Research and Development (R&D) activities required to further develop, evaluate and validate them;
- to make recommendations on how to move this field forward to all stakeholders including action programmes, pest control industry , fruit and vegetable producers, research institutions, and the Joint FAO/IAEA Division.

2. Bait station attributes

2.1 Types of bait stations

There are two main basic types; i) devices carrying on a combination of insecticide and bait in a single formulation. Fruit flies are lured to the bait and ingest a lethal dose of insecticide, and ii) devices with a separated bait and insecticide. Fruit flies are lured to the bait and get in contact with a lethal dose of insecticide.

2.2 Categories of bait stations

There are three general categories of bait stations: i) retrievable at the end of the harvesting season, suitable for commercially fruit production; ii) biodegradable that can remain in the field, until they are degraded; suitable for action programmes, and iii) direct application to a substrate.

2.3 Components of bait stations

Bait stations consist of an attractant, a killing agent and a device which contains both of them.

It is highly recommended that the attractant should be female-biased. Although there are powerful male specific attractants, as Methyl Eugenol, its effect in suppressing male populations has little effect on the overall fruit infestation when used in bait stations for control purposes. However, powerful male specific attractants can be successfully used in eradication programmes to eliminate pest population by application of the "male annihilation" technology.

The killing agent can be contact, consumable, or pathogenic. This agent can also be fast acting or slow acting, including by autodissemination.

2.4 Ideal bait stations attributes

- Control should target female populations;
- Low cost in terms of attractant, killing agent and device;
- Attracted flies should not be trapped and retained;
- Long lasting attractant and toxicant, which allow low labour inputs in view of reduced need for servicing opposite to the case of traps;
- Ease of use, disposable and/or biodegradable;
- Highly selective to suppress only the target population;
- Its effectiveness should be as good as or better than the current ground bait sprays based on insecticide/bait combination which is up to now the standard method for suppressing female/male fruit fly populations;
- Device used should be amenable to a variety of attractants and toxicants;
- Organic and/or low toxicity of the killing agent, which allows safer deployment and low environmental impact, particularly to other beneficial insects as bees and parasitoids;

2.5 Range of applications

The range of applications should be as wide as the use of the conventional ground or aerial bait sprays to suppress fruit fly populations in infested areas or to prevent/eradicate localized populations. An additional advantage to the conventional ground sprays, is that bait stations, if effective, can reduce the amount of active ingredient applied per unit surface. The applications can be:

- As a preventive measure in buffer zones to protect fruit fly free areas from females immigrating into the pest free area;
- As preventive or curative measure in areas of low pest prevalence to keep fruit fly populations on the desired low level. This can be used as part of systems approaches or post-harvest treatments in low and high-input commercial fruit and vegetable orchards for export or local markets;
- As suppression measure to reach the required pest prevalence levels before releases of sterile flies or in hot spots and well known pest reservoirs in area-wide eradication programmes;
- As apart of the control measures in eradication of outbreaks in pest free areas.
- As apart of the suppression measures in organic farming.

Bait stations are placed in hosts or shelter trees in backyards, public parks, town's streets and other common areas bearing host trees, premises and abandoned groves around fruit commercial areas, protected natural areas, difficult to access areas and so forth.

3. Status of development of bait stations

Bait stations developed locally are common. However, their efficacy is generally not well known. Harmonized research protocols would help the development, evaluation and validation of local bait stations. Guidelines for field use would help standardize their use.

The following tables summarize the bait stations in use or under development, current applications, and follow-up actions. Three categories of bait stations are presented: for female populations (Table 1); for female and male populations (Table 2) and for male population (Table 3).

Table 1. Bait stations for females and current status.

Bait Stations	**Status**	**Applications**	**Follow-up Actions Required**
Spheres (ammonium salt + methomyl)	Basic research	Female suppression of *Bactrocera oleae*	Development
Cardboard ammonium salt + Pheromone	Commercially available (*Suterra*)	Female suppression of *Bactrocera oleae*	None

Table 2. Bait stations for females and males, and current status.

Bait Stations	**Status**	**Applications**	**Follow-up Actions Required**
Killing bags, corn cobs, sponges, plastic bottles, etc, with protein bait and killing agent.	Locally used	Suppression of various fruit flies	Validation
M3 ™	Commercially available (*Biagro*)	Suppression of *Ceratitis capitata*	Validated, but needs to be improved
Spheres (ammonium acetate+ trimethilamine + methomyl)	Basic research	Suppression of various fruit flies	Development
Solbait + model 24	Basic research	Suppression of various fruit flies	Field evaluation
Gum stick wax matrix	Basic research	Suppression of various fruit flies	Evaluation (longevity of attractant)
Dipped lure wax matrix	Basic research	Suppression of various fruit flies	Field evaluation
Gel (Moreno bait station) + SPLAT	Basic research	Suppression of various fruit flies	Field evaluation
Magnet-med	Commercial available (*Suterra*)	Suppression of *Ceratitis capitata*	Field evaluation
Magnet-med (phase II)	Basic research (*Suterra*)	Suppression of *Ceratitis capitata*	Field evaluation
Magnet-oli	Commercially available (*Suterra*)	Suppression of *Bactrocera oleae*	Field evaluation
Melolure plug	Basic research	Suppression of *Bactrocera cucurbitae*	Field evaluation
Waste brewers yeast (sponge)	Basic research	Suppression of various fruit flies	Field evaluation
Red spheres	Commercially available	Suppression of *Rhagoletis* spp.	Field evaluation (reduction of cost)
Yellow spheres	Commercially available	Suppression of *Anastrepha* spp.	Field evaluation (reduction of cost)
EPA lure and kill	Basic research	Suppression of various fruit flies	Field evaluation

Table 3. Devices for suppression of males, and current status.

Devices	Status	Applications	Follow-up Actions Required
ME (Methyl Eugenol) fibre blocks or other absorbents materials	In use	Male annihilation for suppression (in combination with other measures), eradication, or exclusion of ME-responding *Bactrocera* spp.	None
Amulet ME ^{TM}+ fipronil	Commercially available (*Aventis*)	Male annihilation for suppression, eradication, or exclusion of ME-responding *Bactrocera* spp.	None
Amulet CL^{TM} + fipronil	Commercially available (*Aventis*)	Male annihilation suppression of CL (cuelure)-responding *Bactrocera* spp.	None

4. Requirements for development, validation and application

Like ground bait sprays, bait stations is not a stand-alone control method for effective fruit fly suppression but should be integrated with a series of other control methods. Bait stations should be an effective complementary tool either for area-wide suppression, eradication and exclusion scenarios as for use in fruit and vegetable commercial areas aimed at producing commodities for export and local markets.

The timing of deployment of bait stations in the field and the layout of the bait station deployment should be based on pest and host ecology data. These data should include information on biotic factors such as overwintering/aestivation of populations, availability of host/shelter trees, breeding sites, fruit host phenology, and also on abiotic factors such as temperature, humidity, rain, winds, etc.

In commercial crops bait stations should be deployed in the field early to prevent population build-up. A homogenous layout of bait stations would be the most common application in areas with uniform host distribution. However, deployment in hot-spots or random layouts could be used for highly patchy or unknown pest and host distributions. Another option is the use of a gradient of bait stations with higher densities in the periphery to protect the target area, as it is currently recommended when applying ground baits sprays in commercial orchards or for protecting places of production surrounded by an area of low pest prevalence as a buffer.

Densities of bait stations should be determined based on a number of factors including pest density, occurring pest physiological stage, efficiency of the attractant and killing agent, phenology, host density and objective of the programme. For commercial areas value and susceptibility of the host can also be taken into consideration. In this latter case, there is plenty of information pointing out that in a single host species there can

be some varieties that are more susceptible than others so that density of bait stations may vary in each case.

The Joint FAO/IAEA Division in partnership with many collaborators and stakeholders has developed standardized methodologies for bait station research (FAO/IAEA 2007). These methodologies have recently been used in Argentina and Spain to evaluate bait stations and mass trapping. Further efforts are required to improve them.

Field evaluation of bait stations should include:

- Comparison of effectiveness with the conventional international standard. Particularly with the ground bait sprays internationally used. These can be the standard combination of malathion/hydrolysed protein and/or GIF-120 spinosad baits;
- Evaluation at a sufficiently large scale to determine cost-effectiveness;
- Use of an area-wide approach, including buffer zones, to minimize the distorting effects of immigrating flies that are attracted to the core area from the surrounding areas;
- Population sampling combining traps for adults and fruit sampling to determine larval presence in fruit. Adult trapping allows for self-correction (results can be analysed during the test), but ideally the final evaluation should be based on percentage of fruit infestation just before harvest.

Additionally, cost-benefit analyses needs to be conducted as decision support tools to determine the returns on investment for bait station deployment (materials, labour and fruit losses) in comparison first, with the standard control option like the ground bait sprays, and second with other control options including mass trapping.

5. Research and development (R&D)

5.1. R&D needs for bait stations

Long lasting attractants: The target half-life in the field for female attractants in bait stations should be at least 4 months. For surveillance of medfly and some *Anastrepha* and *Bactrocera* species the 3 and 2-component attractant lasts 4 months.

Long lasting killing agents: An improved formulation to achieve 4 months longevity of killing agents (to match the longevity of the attractants) through proper use of adjuvants. Formulations of deltametrine are known to last a minimum of 6 months.

Balance between attractant and killing agent longevity: Achieve a balance by matching the minimum longevity of the attractant and killing agent.

Safety of killing agents: Killing agents needs to be biodegradable or environmentally inert. Proper labelling of bait stations and open devices are important since safety and environmental issues are a priority.

Stronger attractants: Stronger female attractants are needed for *Bactrocera spp* (including *B. oleae)*, *Anastrepha* spp, and female attractants for *Dacus* spp., particularly those species that do not respond to the male attractants.

Development of female attractants for other species: Previous research has shown that use of female-biased attractants has been a very effective approach for fruit fly

suppression. Targeting the female population has long term-benefits for sustained pest control. Investment needs to be made in the development of host-based lures that attract females flies (e.g. a cucumber-based lure for melon fruit fly, guava-based lure for *Anastrepha* spp., etc.).

Bait station devices: The devices for bait stations may be customized for each species and microenvironment, although it would be better to have a generic device, particularly for those regions where several species of fruit flies of economic importance coexist in the same commercial host. Besides the lure and killing agent, bait station devices should incorporate, if possible, visual cues in their design. Devices can be:

- **Retrievable.** These devices must be convenient to deploy and retrieve individually. Safety and disposal issues are of particular importance for this type of bait station and must be properly addressed.
- **Biodegradable.** This is an ideal requirement, but not indispensable. Deployment must also be convenient; however, there is no retrieval. Target time to degrade a bait station should be within 1 year.
- **Directly applied.** Deployment is not on an individual basis as in the case of the bait station devices, but improvements are needed for the delivery (application) technology. Since this represents unprotected bait, safety and environmental concerns are an even higher priority.

5.2. R&D needs for procedures

Densities: The attraction ranges of different bait stations need to be estimated to determine their proper spacing. The competitive influence of host volatiles should be better understood. Critical research is needed for each pest species and their main commercial hosts.

Statistics: Research studies must standardize methodologies for experimental design, analysis, and determination of efficacy. Standard methodologies for evaluation of bait stations in the field were developed and are in use (FAO/IAEA 2007). 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 relies on statistically-derived fruit sampling. Fruit sampling procedures need to be further developed and incorporated into bait station research protocols.

Deployment: The deployment will be based on prior experience and knowledge of infestation patterns. If not known, begin with a homogeneous distribution of bait stations. Ultimate deployment design must take an area-wide approach, and integrate with other pest management practices.

5.3. Cost-benefit

An accurate cost-benefit analysis of all elements is a critical component of determining the utility of a particular bait station. This technology must be competitive with the standard conventional ground bait spray applications and other alternative approaches, like mass trapping.

5.4. Prioritization of the R&D

The participants of the Consultant Meeting prioritized the above R & D needs (each consultant ranked the five most important ones). Long lasting attractants and development of female attractants for other species, were listed number one by four of the twelve participants. All other activities got only one or no nomination as top priority.

In relation to total votes (ignoring the priority and calculating just based on nominations), cost-benefit, densities and long lasting attractants were listed respectively by 10, 8 and 7 of the 12 participants). All other activities received 5 or less nominations.

6 Task Force

A "Task Force on Bait Stations" was recommended to further develop the technology. The major players would be: FAO/IAEA Insect Pest Control Subprogramme; action programmes, insect control industry (suppliers of products) government research institutions and industry (fruit and vegetables producers/exports associations).

This strategy document was prepared and will be used as a guideline to further develop the technology. The group will follow-up through conference calls, e-mail and meeting once every two years.

6.1. FAO/IAEA Insect Pest Control Subprogramme

The Joint FAO/IAEA Insect Pest Control Subprogramme was requested to take the lead in coordinating the Task Force. In order to evaluate and validate improved bait stations in-field, some individual research contracts will be provided to research institutions and action programmes that have the capacity to work under the required testing conditions, including an area-wide approach and the evaluation of fruit infestation

6.2. Action programmes

Bait stations will provide action programmes with another tool to suppress fruit fly populations, alone or integrated with other pest suppression technologies. Therefore, as other important end-users of this technology, it is in the interest of action programmes to invest in bait station technology development. Action agencies are also well-placed to conduct area-wide evaluations to validate this technology, because they have human resources available to conduct large field trials.

6.3. Research institutions

The role of research institutions will be to contribute basic research in terms of developing and evaluating attractants, killing agents and formulations to the development of a cost-effective bait station according the above-described R & D needs.

6.4. Pest control industry

There is no doubt that there is a considerable unexploited market for cost-effective bait stations. Success of bait station technology will require pest control industry involvement and cooperation with the other stakeholders to achieve a reliable, cost-effective and eventually marketable commercial product.

6.5. Fruit and vegetables producers

Political support, input and feedback from grower associations is critical for development of improved pest management tools for economically important fruit flies. As end users of this technology, the growers must communicate their needs, facilitate validation of improved bait stations, and provide updates as progress is made.

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