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Area-Wide Control of Insect Pests

From Research to Field Implementation

Producir cientificamente OK

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Establishment of a Mediterranean Fruit Fly *Ceratitis capitata*, Fruit Fly Parasitoids, and Codling Moth *Cydia pomonella* Rearing Facility in North-Eastern Brazil

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ABSTRACT The Mediterranean fruit fly *Ceratitis capitata* (Wiedemann) is a major pest of fruit crops worldwide and its presence in many countries poses a threat for production and export. The methodology that has been integrated in many countries to contain, to eradicate, or to suppress Mediterranean fruit fly populations is the sterile insect technique (SIT). Besides the Mediterranean fruit fly, *Anastrepha* fruit fly species of quarantine importance are also important pests affecting fruit crops in Brazil. Parasitoids that are natural enemies of fruit flies will be mass-reared, together with Mediterranean fruit fly and *Anastrepha* species in the facility that is being established in Juazeiro, Bahia with the objective of suppressing fruit flies in the expanding commercial fruit production areas in the São Francisco river region. To take advantage of the availability of a large complex of buildings, the facility will eventually also produce sterile codling moth *Cydia pomonella* (L.), a pest recently introduced into southern Brazil, where it threatens the continuously growing apple and pear industries. The production of sterile Mediterranean fruit flies and sterile codling moths, as well as sterile host larvae for natural enemy production, will use gamma radiation as the sterilization method. The area-wide integrated pest management (AW-IPM) approach, including the release of these beneficial insects in the field, is the most effective means to control (suppress or in some situations even eradicate) such pests. The consumption of fresh fruits has increased worldwide and production in Brazil, either for domestic or export markets, has been intensified in the last decade. As food safety is becoming a major concern for consumers, the use of environment-friendly technologies such as the SIT will be increasingly required. The final clients for the sterile flies and moths will be the fruit growers. The foreseen weekly production of 200 million sterile Mediterranean fruit flies and 10 million *Diachasmimorpha longicaudata* (Ashmed) wasps will be released in the tropical fruit-growing areas of northern Brazil: Bahia, Pernambuco (São Francisco Valley), Ceará, north of Minas Gerais and north of Espirito Santo. The sterile codling moths would be sent by air to the apple and stone fruit production areas in the south of Brazil, Rio Grande do Sul and Santa Catarina, where this pest species is still confined to urban areas and hence amenable to eradication.

KEY WORDS *Ceratitis capitata*, *Anastrepha* spp., *Cydia pomonella*, *Diachasmimorpha longicaudata*, area-wide control, sterile insect technique, Brazil, São Francisco river valley

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1. Introduction

The sterile insect technique (SIT) is used in many countries as part of an area-wide integrated pest management (AW-IPM) approach to control (suppress, contain, prevent or eradicate) the Mediterranean fruit fly *Ceratitis capitata* (Wiedemann) and other fruit fly pests. This expanding use has proven successful in protecting critical production areas from Mediterranean fruit fly infestation and embargos on fresh fruit exports worth thousands of millions of USD. The SIT is incorporated into fruit fly control programmes to minimize the continuous use of insecticides, protect the environment, and meet food safety standards. Fruit fly rearing facilities are in operation in Argentina, Australia, Chile, Guatemala, Israel, Mexico, Peru, the Philippines, Portugal, South Africa, Thailand, Tunisia, and the USA (Hawaii and Texas). Others are being planned or under construction in Costa Rica and Spain, and now in Brazil (Dyck et al. 2005). The Okinawa melon fly *Bactrocera cucurbitae* (Coquillett) mass-rearing facility in Japan is now producing low numbers of insects sufficient to maintain a continuous preventive release programme in the southern-most islands of the Okinawa archipelago that are susceptible to reinfestation since this pest was eradicated from that country (Koyama et al. 2004). In these programmes, the SIT has proven to be successful in the suppression, containment, prevention or eradication of fruit flies (Wong et al. 1992, Hendrichs 1996, Barry et al. 2003, Hendrichs et al. 2005). Other sterile insect factories are in operation to combat lepidopteran pests, screwworms, and tsetse flies (Dyck et al. 2005).

2. Fruit Production in Brazil

Brazil is one of the largest fruit producers in the world (38 million tons in 2004), being first in oranges (18.3 million tons in 2004), second in papayas (1.7 millions tons in 2003) and seventh in mangos (925 000 tons in 2003; also second in exports) (Brazilian Fruits Yearbook 2005). In the last 20-30 years, the federal and some state governments have developed many irrigation programmes in the semi-arid north-eastern part of Brazil focusing on the production of tropical, subtropical, and temperate fruit crops. As a result of such actions, the north-eastern region is the largest producer in the country of mangos, table grapes, melons, bananas, Antilles cherry, and guavas. The cultivated area is continuously increasing and at the end of 2004 there were, for example, 68 455 hectares of mangos in the whole of Brazil, of which about 20 000 hectares are in the São Francisco Valley (Brazilian Fruits Yearbook 2005). Most of the citrus production (800 000 hectares, as well all 35 000 hectares of apples) is concentrated in the southern states of Brazil.

Brazil exports annually around USD 400 million in fresh fruits (850 000 tons, which is only 2% of total production), and USD 1100 million in concentrated juices to Canada, Japan, and the USA, and to countries in the European Union (EU) and in the South Cone Free Trade Agreement (Mercosur) (Brazilian Fruits Yearbook 2005).

To a large extent, the fresh products export market requires some type of quarantine treatment. Fortunately, however, large fruit producing areas in north-eastern Brazil are deemed "low prevalence" in terms of pests and diseases, especially fruit flies. The very low humidity, high air temperature, and lack of host availability year-round keep fruit fly populations low. However, in areas where the harvest time for mangos was extended from the original 2-3 months to 6-8 months due to improvements in technology, wild fly populations can now increase dramatically in a few months. It is exactly in such areas of the North East that the integration of the SIT for suppression is both required and highly feasible.

The new agricultural frontier represented in the semi-arid North East is a consequence of four main factors: (1) improved infrastructure developed through governmental support, (2) high technology such as computer-controlled irrigation, hormone and physiological control of blossoming, IPM techniques, and

advanced postharvest processes, (3) positive environmental factors such as good soil, clean water, low relative humidity, high ambient temperature, and long periods of sunlight, and (4) a new generation of young entrepreneurs.

3. History of the Project

At the end of 2000, a group of researchers proposed the implementation of a Mediterranean fruit fly rearing facility in north-eastern Brazil to the Federal Government of Brazil in response to demands from the private sector for better (i.e. economically feasible and environment-friendly) technologies to control key fruit fly pests in this region. During 2001, the Plant Protection Department of the Ministry of Agriculture, Livestock and Food Supply called a series of meetings to bring together different stakeholders with an interest in the rearing facility. A Mediterranean fruit fly rearing facility working group was created by the Ministry of Agriculture, Livestock and Food Supply to carry out studies to assess the feasibility of a facility. In January 2002, the Ministry of Agriculture, Livestock and Food Supply called for an international mission to visit potential sites for the facility, make a first evaluation of its feasibility, and recommendations concerning the size and numbers of sterile flies to be produced by the facility. The mission from the International Atomic Energy Agency (IAEA), the United States Department of Agriculture (USDA) and Instituto de Sanidad y Calidad Agropecuaria in Mendoza, Argentina (ISCAMEN) recommended that the facility should be sited in the São Francisco Valley (Juazeiro-Petrolina) in the centre of the largest fruit production area of the country and also equidistant from most other fruit producing areas in north-eastern Brazil. This site was also selected because of the availability of an empty cotton processing plant that ironically was shut down due to the collapse of cotton production in the region because of heavy infestation by the boll weevil. The mission concluded that construction of a mass-rearing facility to produce sterile flies (SIT) for suppressing or eradicating medfly is feasible in the north-eastern fruit production areas of Brazil (Enkerlin et al. 2002). In addition the report states that:

> *...this environment-friendly technology, complemented by minimum use of organic bait to lower wild fly populations, is an important addition to the technologies supporting Brazilian agriculture. The introduction of this IPM component opens the door to other pest control tools such as fruit fly parasitoids and expanded use of sterile insects to control other fruit fly species of economic importance.*

Following these recommendations, the Mediterranean fruit fly rearing facility working group carried out studies to define the best legal framework for creating the new entity. Special attention was given to its format in order to avoid inflexibility and excessive bureaucracy, and to enable the establishment of alliances with the federal and state governments, international organizations and the private sector. In November 2002, the Biofábrica Moscamed Brasil (Mediterranean Fruit Fly Facility Brazil) was formally created as a social organization attached to the Ministry of Agriculture, Livestock and Food Supply, and organized with an administration council with federal, state and private representatives, and an executive board with three executive directors.

In January 2003, a technical group was created by the Biofábrica Moscamed Brasil to establish the technical parameters for the rearing facility on premises obtained from the Government of the State of Bahia. This group from the Food and Agriculture Organization of the United Nations (FAO), IAEA and USDA defined the baselines for the facility including the basic drawings, rearing flow, and technical specifications in terms of power and water requirements, air conditioning, and other utilities. Its general conclusions (Cáceres et al. 2003) were:

> *The building site in the State of Bahia located in the city of Juazeiro is ideal if the entire 5-hectares facility could be devoted to the rearing plant. This dedicated use would simplify management and provide adequate space for all pro-*

necessary to reduce populations prior to releases of sterile males, and public relation and extension activities.

Regarding the SIT *per se*, a key element to the success of the programme is the design, construction, and operation of a sterile fly mass-rearing facility capable of producing sufficient sterile insects of good quality and at reasonable cost, in combination with efficient SIT programme implementation and support to growers, the public and government. Since a high degree of responsiveness to clients' needs promotes sustainability, the initial focus of the programme is on effectiveness and cost efficiency unless other mitigating issues take precedence. Factors such as the environment, public health, public and political opinion, and the future direction of plant health regulations could influence the use of the SIT, even if the initial cost efficiency is less than optimal.

5. Plans and Concept

The initial kick-off for the programme was the positive political decision by the Federal Government of Brazil, especially the Ministry of Agriculture, Livestock and Food Supply, with strong support from the Government of the State of Bahia. Providing the plant site was the first step, followed by the building process that required a large investment. The federal and state governments are responsible for all funds earmarked for the building phase (around USD 4.5 million), with the fruit industry providing the essential political support to the government agencies. After the operation is initiated, industry – through the growers associations and cooperative farms – will gradually compensate the Biofábrica Moscamed Brasil for the services being delivered to the farms, which will encompass monitoring and releases of sterile males.

Presently, in most fruit production areas, the trapping system in place is grower-operated with different arrangements in place according to the region and always supervised directly by the Ministry of Agriculture, Livestock and Food Supply or by the state plant protection agencies. Hence the growers are already paying for the trapping services. The proposal now – which is supported by the industry – is to have Biofábrica Moscamed Brasil manage the trapping operations since these provide essential information for use of the SIT and for the other control measures that are needed.

The integrated area-wide approach, fundamental for a successful programme, is the concept to be applied and a public dissemination campaign to explain the concept and its operation will be essential to have large, middle and small growers join the programme. The broad acceptance of, and participation in, the fruit fly management programme is largely expected because a low prevalence of fruit fly populations is one of the requirements to export mangos into the USA and Japan, and the EU also now requires new processes for fruit production.

After the government allocates the seed money to build the facility, the operation is expected to be sustainable within a few years. An additional source of funding could be the export of sterile Mediterranean fruit flies. Although a large number of sterile Mediterranean fruit flies are being produced in other mass-rearing facilities around the world, demand is still larger than this production capacity. In addition, Biofábrica Moscamed Brasil production can be destined for local use in future area-wide IPM projects involving the SIT in other regions of Brazil. For example, the El Pino mass-rearing facility in Guatemala exports millions of flies per week to California and Florida in the USA and also to Israel in the past. Argentina, Mexico, Portugal, and USA mass-rearing facilities in Texas and Hawaii have also supplied other users. Modest amounts of profit obtained from such transactions reduce plant production costs. The ability to ship pupae long distances and the technology under development for shipping Mediterranean fruit fly eggs to international clients, adds greatly to plant utility, financial viability, and overall cost effectiveness.

6. Strategic Alliances

A key aspect for a fruit fly management pro-

gramme that includes the SIT is to have alliances in the national and international arenas. The federal and state governments are the natural national alliances. These are key partners since, amongst others, the importation of biological material from foreign sources requires permits and federal government approval, the transshipment of flies from one state to another requires state government collaboration, and the development of technical alliances with other international entities is dependent on federal and state government participation. Within these, the Ministry of Agriculture, Livestock and Food Supply, the Ministries of Science and Technology and of National Integration, and the state governments through the agencies for plant protection in Bahia, Pernambuco, and Ceará are particularly critical for the success of the programme.

Important support for research and development is provided by two research centres, the Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA)), i.e. Embrapa Cassava and Fruits, and Embrapa Tropical Semi-Arid. Other important partners are the Centre for Nuclear Energy in Agriculture (CENA) and the Institute of Biosciences of the University of São Paulo (USP). These have helped the Biofábrica Moscamed Brasil implementation since the beginning, including in planning, training, carrying out applied research, and permanent overseeing.

In the industry, the Biofábrica Moscamed Brasil has the support from three major grower associations, the Fruit and Vegetables Export Association of São Francisco Valley (Valexport), the Brazilian Fruit Institute (IBRAF) and the Brazilian Papaya Export Association (BRAPEX). The private sector has also contributed financial and political support.

The IAEA/FAO, as international organizations have also given support. This included supporting the first mission to define the site of the plant in 2001, and a current Technical Cooperation Project that covers the endowment of a ^{60}Co irradiator, and the costs of short-term expert visits and training for the newly-hired personnel. Two professionals from EMBRAPA and CENA were trained for three months in the rearing, irradiation and quality control aspects of the Mediterranean fruit fly *temperature sensitive lethal* (*tsl*) genetic sexing strains at the FAO/IAEA Agriculture and Biotechnology Laboratory, Seibersdorf in Austria. Additionally, through the El Pino Mediterranean Fruit Fly Facility in Guatemala, the United States Department of Agriculture's Animal and Plant Protection Service (USDA-APHIS) has systematically provided technical assistance since the beginning of the project, with directors' visits to Brazil, and Brazilian professionals visiting Guatemala for training and obtaining information on the facility in order to design and prepare the operational aspects of the Biofábrica Moscamed Brasil. Finally, ISCAMEN, Argentina, has given technical advice and sent sterile Mediterranean fruit flies for preliminary tests in Brazil.

7. Research and Development Component

The Biofábrica Moscamed Brasil is the first facility in Brazil to produce sterile insects on a large scale and, as a result, there is a small critical mass of trained personnel in the country. There is however, no information regarding the effectiveness of the SIT under semi-arid conditions. A set of experiments and large-scale field tests were planned and are being carried out to answer basic questions concerning the mating competitiveness of *tsl* strain VIENNA 8 (Franz 2005), sterile males competing with wild males for wild females, dispersion and longevity of sterile males under semi-arid conditions and related topics. In collaboration with the Agricultural Research Service (ARS) of USDA, the University of Tessaly in Greece, and the Joint FAO/IAEA Programme, one staff member is leading a group in EMBRAPA to answer these questions with financial support from the Bank of Nordeste.

Large pilot tests are also planned for two

Table 1. *Production and basic biological data of the VIENNA 8 genetic sexing strain colony at USP-CENA, Piracicaba, SP, Brazil.*

Generation[1] (month/year)	Eggs[2] (ml)	Egg viability (%)	Number of pupae (x 1000)	Male viability (%)	Female viability (%)	Sex error in brown pupae (%)	Sex error in white pupae (%)
F_{10} (Dec/04)	12.5	24.7	48	63.1	85.1	1.18	0.00
F_{11} (Jan/05)	19.1	77.2	1257	84.9	80.3	0.30	0.00
F_{12} (Feb/05)	64.3	75.8	1680	76.9	86.6	0.85	0.18
F_{13} (Mar/05)	52.2	63.8	1430	83.5	90.7	0.50	0.00
F_{14} (Apr/05)	98.2	71.6	1390	83.1	89.6	0.26	0.08
F_{15} (May/05)	243.5	68.3	3240	n.a.	n.a	n.a	n.a

[1]The VIENNA 8 pupae received from the FAO/ IAEA Agriculture and Biotechnology Laboratory were from generation F_9 (Carlos Cáceres, personal communication)
[2]Not all collected eggs were used for pupal production

mango areas – 3000 and 5000 hectares – where the Mediterranean fruit fly is historically reported as being of economic importance. Sterile males will be brought from ISCAMEN and released in the experimental areas after a detailed survey and following suppression measures taken when the feral population is high. For these pilot tests, partnerships were established with EMBRAPA, the Bahia Animal and Plant Protection Agency (ADAB), and the University of south-western Bahia (Universidade Estadual do Sudoeste da Bahia (UESB)) to have good entomological and logistical support to carry them out.

At the USP-CENA laboratories, the VIENNA 8 strain received from the FAO/IAEA Agriculture and Biotechnology Laboratory in December 2004 was successfully adapted to a larval diet, which was developed in 2002 with local ingredients (Walder 2002). This diet contains sugarcane bagasse as a bulking agent, wheat germ and brewer yeast as protein sources, sugar and wheat flour as phagostimulants and carbohydrate sources, an antibiotic as bacterial growth inhibitor, sodium benzoate to avoid fungal growth and hydrochloric acid as pH regulator. The rearing protocol is very similar to that recommended by Cáceres (2002). Studies using several quality tests including gamma sterilization are being applied under laboratory conditions (FAO/IAEA/USDA 2003). After six generations the strain shows good quality and stability (Table 1), enabling colony expansions to be planned for subsequent generations.

USP-CENA will be responsible for maintaining the original strain imported from the FAO/IAEA Agriculture and Biotechnology Laboratory and transferring it to the Biofábrica Moscamed Brasil when the mass-rearing process starts. Also the tests for improving the local diet and the quality control of the rearing will be supervised by USP-CENA.

8. Conclusions

The location of the Biofábrica Moscamed Brasil in the São Francisco Valley is right in the centre of mango and many other fruit production farms. This close proximity to production areas should promote more private sector interest and commitment. Private sector investment would be enhanced if the Mediterranean fruit fly rearing facility was an integral part of the community where the stakeholders live and work, since local producers and public sector officials are in a better position to support the plant and resolve any

problems that might arise locally or regionally.

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