Model Business Plan for a Sterile Insect Production Facility

Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

IAEA
International Atomic Energy Agency

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FOREWORD

For over 50 years the sterile insect technique (SIT) is a pest control strategy which has been used for eradication, and more recently for suppression, containment and prevention, of unwanted insect pest populations. Examples of successful applications of SIT, almost always applied in conjunction with other control methods in an area-wide integrated approach, are available from around the world. The development and application of SIT has relied overwhelmingly on public or donor initiative and funding throughout its history, although the private sector has always been involved as participants, cooperators or partners in funding.

The demand for SIT, and therefore the market for sterile insects, has increased in recent years. This increase coincides with the introduction of new pests through the expansion of global trade and, at the same time, widespread pressure to find alternatives to pesticides. Recent improvements in the technology supporting SIT facilitate its application and suggest lower costs can be achieved. The conditions are therefore met for a greater commercialization of the technique to bring it in line with other pest control approaches that are fully integrated into a market approach. Several challenges arise, however, in pursuing sterile insect production as a commercial venture, ranging from intellectual property protection to pricing of the product. Routine insurance requirements, for instance, are complicated by the biological aspects of the business.

This report is aimed at facilitating private sector involvement in the production of sterile insects for use in pest control. It provides guidelines and tools to support the development of specific business plans for a new SIT venture. By providing an international perspective on such issues as initial capital costs and recurring operational expenditures for a sterile insect facility, it may be used to evaluate the feasibility of proceeding with the construction or expansion of a sterile insect production facility. Informed decisions will allow government planners and private investors alike to account for the opportunities and risks unique to SIT and to plan accordingly.

The Joint FAO/IAEA Programme is grateful to M.M. Quinlan (Interconnect, London, United Kingdom) and J.D. Mumford, J.D. Knight and J.M. Stonehouse (Imperial College London, United Kingdom) for conducting the original study submitted in 2002 to the Department of Technical Cooperation through its Interregional Project INT/5/145, and for carrying out some revision for this publication.

The on-site studies presented in the annexes were developed by these authors in conjunction with experts in each country. In this regard, the IAEA wishes to thank A. Larcher-Carvalho, A. Ait El Mekki, and M.H. Dhouibi for these additional contributions. The IAEA officer responsible for this publication was W. Enkerlin of the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture. Please note that care should always be taken to update and verify specific market and financial information before investing in any activities.

EDITORIAL NOTE

The use of particular designations of countries or territories does not imply any judgement by the publisher, the IAEA, as to the legal status of such countries or territories, of their authorities and institutions or of the delimitation of their boundaries.

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Section 1 Summary

Following its original development over 50 years ago, the sterile insect technique (SIT) has been used for suppression, eradication, containment and prevention of unwanted exotic insect pest populations. Examples of successful applications of SIT, almost always in conjunction with other control methods in an area-wide integrated management approach, are available from around the world.

Interest is rising in the use of the SIT as a method of pest control, as demonstrated by the number and scope of current field applications, the number and output capacity of sterile insect production facilities, and the number of inquiries to the International Atomic Energy Agency (IAEA) and the Food and Agriculture Organization (FAO) Joint Division of Nuclear Techniques in Food and Agriculture. There remains substantial demand for sterile New World screwworm (NWS), the first species with pest populations eradicated using the SIT. Tsetse was successfully eradicated in Zanzibar, Tanzania, in 1996, triggering the African Union's Pan African Tsetse and Trypanosomosis Eradication Campaign (PATTEC) involving the planning for much larger tsetse programmes. A continuing increase in Mediterranean fruit fly (Medfly) production facilities gives testimony to the rising demand for suppression, eradication and prevention of this fruit pest. Along with a range of several other fruit fly species, crop pests successfully controlled with the SIT include codling moth, pink bollworm, sweet potato weevil and onion fly. Numerous other species have been targeted with this approach, and others are under study.

The driving forces for this rising interest include an overall increase in demand for a more effective pest control to reduce losses to major pest insects, and to comply with animal health and phytosanitary requirements that justifiably restrict global agricultural trade. Other driving forces are the ongoing concerns over control of exotic invasive pests, the development of pest resistance to insecticides, and cases of important pesticides and fumigants being banned or restricted by regulatory authorities. In addition, an increased awareness of the link between poverty, food production and the environment has brought greater attention to the challenge of developing effective pest control that is environmentally benign. Consumer concerns about pesticide residue on foods and the environment further contribute to this rise in demand for sustainable alternatives to pesticides as part of an integrated control strategy for key insect pests.

Involvement of private sector investment and commercial companies in the various components of SIT application should be encouraged, in view of the potential for large-scale SIT programmes for public health (tsetse, for example) and the more commercially-driven demand for the incorporation of the SIT in the control of insect pests of horticulture and other crops. Yet presently, there are challenges for private investors to become involved in sterile insect production – an activity still largely dominated by government-funded projects. Governments can absorb more risks than relatively small companies and produce at-cost or even subsidized sterile insects. Furthermore, routine insurance needs are complicated by the biological aspects of the business. Therefore "biological insurance" in the form of separate modules at each location, backup production facilities or colonies at other sites, or pricing that allows for excess production/colony maintenance should be designed into each species sector. Donor agencies may need to take the lead on finding the appropriate form and level of this type of production backup, especially for SIT programmes aimed at public good (e.g. for human or animal health, such as tsetse fly control).

The physical plant of commercial production will be based on experience of government funded facilities, especially for sterile fruit flies and NWS production. The choice between automation and low technology will be related to which species is under mass production as well as the cost of labour, maintenance capacity, and other issues in the selected country. Some automation will enhance the quality of the sterile insects, for instance for moths which suffer more from handling than some other insects. Modular versus single unit design is another decision, although modular is generally more popular for recent constructions.

Environmental issues to consider include those for any other small industrial site. Some facilities are obtaining ISO certificates to indicate the proper management of environmental factors. Unique issues relate to biosecurity of this type of facility, however, for example the prevention of the escape of the species under production. There are also potential hazards to the sterile insects themselves that must be kept out of the production process. Such hazards are identified and discussed in this Model Business Plan.

It is possible to integrate all of the above factors into commercial production through appropriate pricing of the final product, the sterile insects. Various methods for pricing are outlined, although a cost-based method is the only one used for sterile insects to date. With the information available on facilities producing sterile Medfly, a linear regression shows that the modular approach to production counteracts the expected level of “economies of scale” for the construction phase. Instead, these economies appear during the operational phase.

The “bottom line” for investors will be the potential and likelihood of profit resulting from such a venture. The Model Business Plan concludes with a financial model for relating capital outlay, operating costs, proportional use of the facility’s capacity, desired profit levels and the price charged for the final product. This model may be applied in its electronic form to demonstrate alternative scenarios by using varying costs, loan interest rates, competitive prices and so forth. The model can assist in initial feasibility studies, as well as in the periodic review of an operating facility’s business plan.

In view of the relative richness of data, the financial model represents a sterile Medfly production facility only, but could be adjusted to other types of facilities. The model allows the comparison of costs in a particular location with summarised international costs. The purpose is not so much to negate the possible benefits of a new site if it appears more costly than the international example, but rather to highlight which assumptions underlie the proposed business, in case these assumptions require adjustment. This also reveals areas for further exploration by investors who may choose other locations or request revision of the plans before their initial capital outlay.

A number of studies were conducted to enrich the overall Model Business Plan and are reported in the Annexes. The financial model was applied to a proposal for a then-new facility for production of sterile Medfly in Slovakia. Despite a comprehensive and well prepared feasibility study, the model facilitated consideration of variation in outcomes based on probability of events, and thereby resulted in more robust assumptions closely aligned with international experience. The other on-site studies for fruit fly control, specifically Portugal, Morocco and Tunisia, demonstrated that, at the time of the original study, a demand existed for sterile Medfly in the Mediterranean region far beyond the supply. Another study considered the status of date or carob moth as a pest worldwide and comments on the demand for the SIT as an important addition to integrated control of that pest of dates, citrus, nuts and other cash and food crops.

Although the Model Business Plan provides a broad overview of the current situation of the SIT, it clearly supports the need for private investment and commercial operations to respond quickly to existing demand and to join as partners for completing the research that will open up new demand for other species. Market studies will require frequent revisions as a range of issues impact annual demands. Exciting improvements in the technology suggest lower costs can be achieved, thus supporting further the use of this pest control method as part of integrated area-wide management strategies.

Finally, if private facilities are to succeed over time, government-supported ones must either charge prices in line with the real costs (including capital outlay) or cease from supplying the market except as emergency backup. To date, government-funded facilities were not intended to supply other country programmes and demand has exceeded supply. Many countries will welcome, therefore, the commercial interest in sterile insect production.

Section 2 Introduction to the project

This report was originally prepared in 2002 as part of the Interregional Project, *Insect Pest Control Using the Sterile Insect Technique*, under the auspices of the International Atomic Energy Agency (IAEA), Department of Technical Co-operation, with technical support from the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture. The Joint Programme has facilitated the more recent revision of the central text. The concept of the report was to create a "generic" business plan aimed at private sector involvement in the production phase of sterile insects for use in pest control. This report is a guideline or tool to support the development of more specific business plans that will need to be prepared on a case by case basis, taking into account the species to be reared and the location of the facility. This report provides the international perspective on a number of issues of importance for construction and management of the sterile insect production facility. While some of the points raised will be well known to anyone working in the sector and are included simply to inform potential investors, hopefully other findings present new ideas for production facility managers as well, whether private or government.

The SIT has existed for over 50 years and has demonstrated successes in all parts of the world. The time has come for greater commercialization of the technique to bring it in line with other pest control approaches that are fully integrated into a market approach, pesticides being primary among these. Commercial ventures carry risk. This report may be used to support the decision to proceed with the construction or expansion of a sterile insect production facility. A conclusion that a specific proposed production facility is not commercially feasible, and that an efficient alternative solution can be adopted, is equally valuable. Informed decisions will allow government planners and private investors to weigh the supply with the demand for sterile insects, to consider costs against possible income, and to plan accordingly.

2.1 History of SIT and the FAO/IAEA collaboration

The SIT consists of mass production of the target insect species[1], sterilization of the insects (historically almost always using radiation) and release into the field on a sustained basis and in sufficient numbers to achieve appropriate over-flooding ratios in relation to the wild population. Sterile males find and mate with wild fertile females, transferring infertile sperm. The objective is to have no resulting viable offspring (in either the first or subsequent generations), thus leading to a reduction in the targeted pest population. Although SIT is appropriate for only certain pest species and under particular conditions (discussed in Section 4.1), the technique can have important advantages in those cases (Figure 2.2).

The SIT has been used for suppression, eradication, containment and prevention programmes of both plant and animal pests (e.g. Medfly and NWS). There is unmet demand for sterile insects to use in SIT programmes (e.g. in the Mediterranean Basin; FAO/IAEA 2000a) and additional facilities are being constructed to meet this demand. Because of the historically limited number of facilities for rearing and sterilization, sterile insects are often transported for release in other locations. Transboundary shipments have gone from production facilities in the Americas to at least 22 countries in four continents (FAO/IAEA 2001a; Enkerlin and Quinlan 2004). The construction and operation of additional facilities, for a wider range of

[1] Arthropods, a phylum under the kingdom of Animalia, includes various classes (Figure 2.1). Pest species discussed throughout this report are from the Class Insecta (Figure 2.2).

target species, will alleviate the pressure on these few facilities and allow the technology to move more solidly into the commercialization phase.

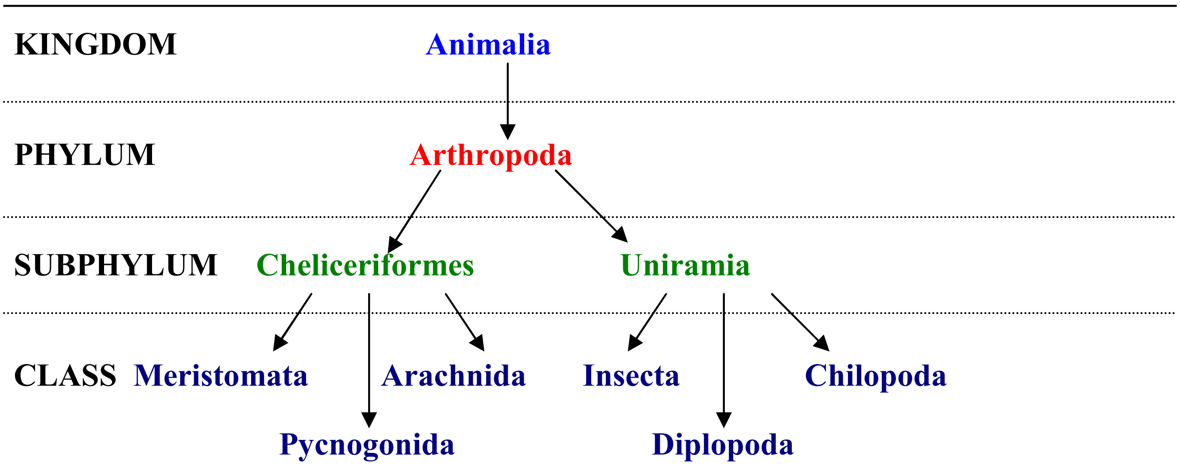

FIG. 2.1. The biological (taxonomic) context of insects and arthropods.

The IAEA serves as the world's foremost intergovernmental forum for scientific and technical cooperation in the peaceful use of nuclear technology. Established as an autonomous organization under the United Nations (UN) in 1957, the IAEA represents the culmination of international efforts to make a reality of United States of America (USA) President Eisenhower's proposal in his *Atoms for Peace* speech before the UN General Assembly in 1953. He envisioned the creation of an international body to control and develop the use of atomic energy. Today, IAEA's broad spectrum of services, programmes, and activities is based on the needs of its current 144 Member States (as of March 2007).

Since the early days of the IAEA, technical cooperation has been offered to member countries. For the first 30 years, the Technical Co-operation Programme focused on improvement of human capital by building institutions and providing improvements to facilities. These projects, using IAEA funds, were relatively small and lasted no more than a year for each project. After larger multi-year projects attracted external funding from the United Nations Development Programme (UNDP) in the 1970s, Technical Co-operation introduced its own multi-year programmes.

Systematic evaluation of the impacts of projects has guided the Agency since the 1980s. A philosophical shift occurred later that decade as programme objectives moved from initial capacity building to the support of policy and strategic planning. There is currently a requirement for measurable impacts on social or economic needs of the beneficiary countries, beyond the impact on the institution conducting the project. The current Technical Co-operation Department supports the overall IAEA Strategy and is the primary channel for achieving one of the three strategic aims of IAEA, namely technology transfer.

The necessity for combining agricultural and nuclear expertise was foreseen by the international community more than 30 years ago when the FAO, a sister UN body, and the IAEA began working together in the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture. Today, the foundations for continuing scientific advances are well established: The Joint Division has more than 900 active research contracts and more than 500 research agreements providing technical supervision and support to these research projects around the world. In 2005 the IAEA awarded US$7.4 million for its coordinated research activities.

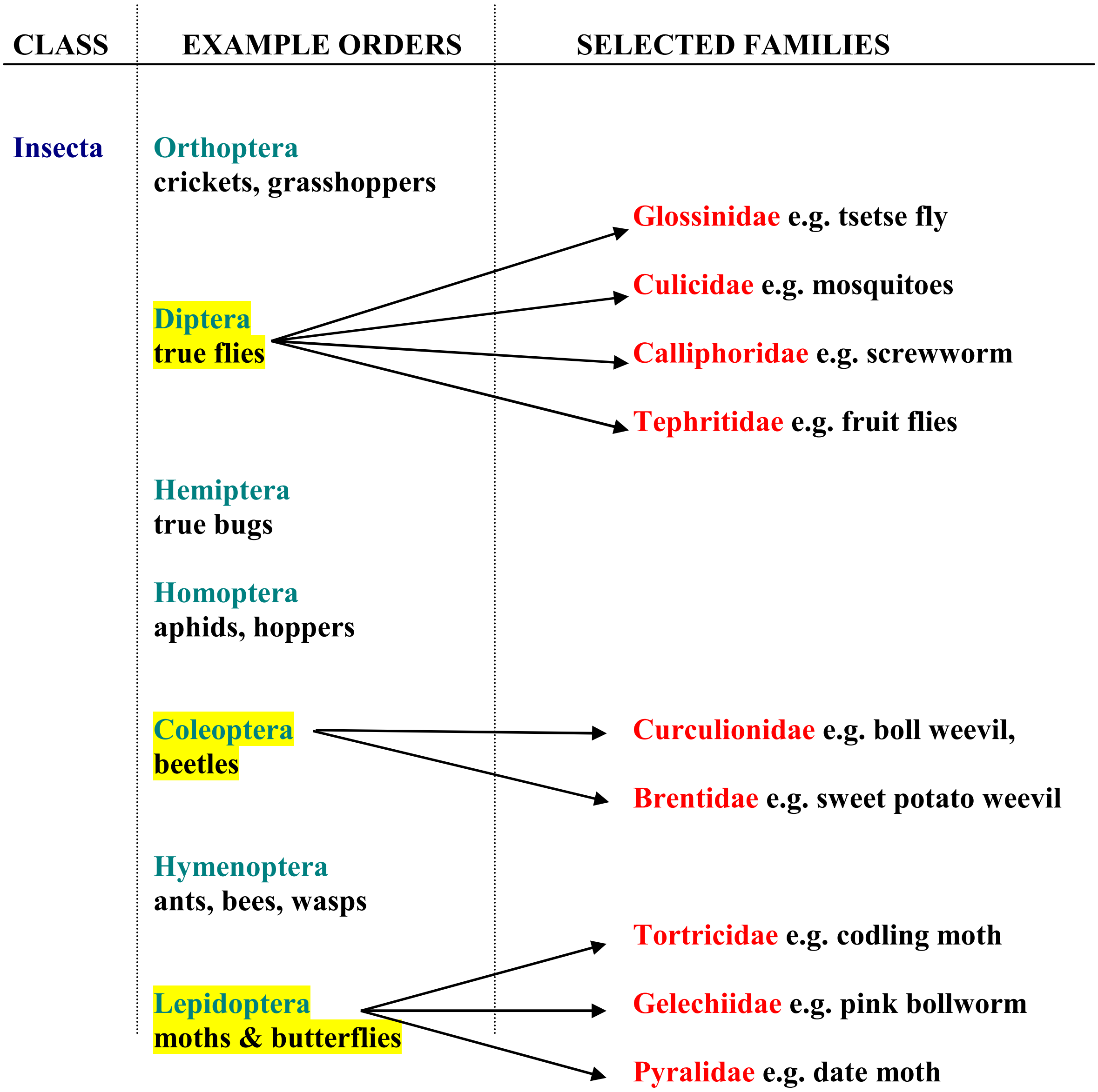

FIG. 2.2. Some orders of the class Insecta, with examples of orders (highlighted in yellow) and selected families currently targeted using SIT.

The SIT has advanced under the stewardship of the Joint FAO and IAEA Programme. The project resulting in this report, a Model Business Plan, combines the programme management and strategic planning experience of the Technical Co-operation Department with the technical expertise of the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture, specifically the Insect Pest Control Section and the FAO/IAEA Agriculture and Biotechnology Laboratory, located in Seibersdorf, Austria. Their mutual commitment is to increase global access to the results of advancements in SIT. Involvement of the private sector appears to be one important mechanism for expanding application of the SIT.

2.2 Driving forces for change in current pest control practices

The demand for SIT, and therefore the market for sterile insects, is increasing[2]. This coincides with a trend to find alternative pest control methods and with the introduction of new pests through new trade routes.

2.2.1 New demands for pest control

The classification of an insect as a plant "pest" or an animal "disease"[3] is a value judgment based on the situation in which the damage caused by a particular species to plants or animals is considered significant. The official international definition of a plant pest, for example, is: "Any species, strain or biotype of plant, animal or pathogenic agent, injurious to plants or plant products" (IPPC 2006).

In the past, pests moved through natural migration or on cargo ships and were more likely to be grain pests or have long dormant periods to survive these journeys. Today, new pests are more likely to be insects with cryptic stages making their detection in fruits, vegetables or flowers difficult. Travelling by air cargo, pests may arrive without the need for long survival periods in transit before being accidentally released into a new environment. They may be coming on different trade routes than in the past, opening the door to totally different introductions. The influx of pests is increasing if for no other reason because of the vast increase in international trade and passenger travel (Nugent et al. 2001).

Although ecologists argue that any species can become invasive or injurious under the right conditions, certain extrinsic factors and biological or life history traits predispose some insect species to become pests or "outbreak" species — species that increase in numbers relatively unchecked and which can cause substantial economic damage to agricultural produce or valued ecological systems. These factors are highlighted below.

Reproductive traits

The ability to reproduce rapidly when numbers are low can promote outbreaks. Asexual reproduction, or parthenogenesis, is a mechanism for females to produce genetically identical copies of themselves, thus avoiding the "costs" and risks associated with both finding a mate and with the act of mating. This reproductive trait, used by species such as aphids, permits rapid increase in population size to injurious levels.

Wide host range

A species that can survive through its life cycle on a wide range of hosts is more likely to become a pest. The ability to switch from a native species to an introduced crop species also opens up a new and readily available food source. Modern monoculture crops can provide abundant resources for their herbivores and at the same time discourage or provide insufficient resources for polyphagous predators and other natural enemies.

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[2] This can be measured by the number of requests to the FAO/IAEA for assistance in starting SIT projects, the rise in national and regional governments conducting their own planning and feasibility studies, continuing participation in training in SIT by officials from new locations and the actual number of government-run programmes in implementation.

[3] In the international veterinary field, an animal disease includes insects that directly attack animals or those that serve as vectors of disease, in addition to pathogenic diseases. For more discussion of this, and of what are the "worst" pests in the world, see Nugent et al. 2001.

Freedom from co-evolved predators or parasites
Alien or exotic species that are newly introduced to an environment will often have few or no natural enemies. Where there are suitable host resources and climatic conditions, some exotic insect species can spread rapidly.

Ability to survive under a wide range of conditions
Some species are severe pests in a few geographic areas but completely insignificant in others due to the climatic conditions that will either prevent survival of the species when introduced or limit it seasonally. (The changes in climate occurring with global warming may, in fact, favour wider distribution of insect pests and increased damage.)

Cultural methods favouring invasive traits
Cultural methods, such as continuous cropping without fallow periods or crop rotation, can permit the build up of substantial pest populations. Historical and contemporary use of broad-spectrum insecticides can rid an area of natural enemies whilst leading to the evolution of insecticide resistance in the target pest.

The driving forces for change in the current approach to pest control include the new demands for pest control in agriculture, forestry, animal husbandry and for environmental protection.

2.2.2 Advances in alternative methods of pest control

Alternative methods of pest control were used for decades before the advent of the inexpensive chemical options that took priority from the 1940s up to today. Only the restriction of some frequently applied post-harvest pesticides (e.g. the fumigants ethylene di-bromide (EDB) and more recently methyl bromide (MB) led to a resurgence in research and use of alternative commodity treatments over the past 15 years (Hallman and Quinlan 1996; Quinlan 1985). The ban of EBD was due to new findings regarding the toxicity of these pesticides for humans, but increased environmental awareness has also provided a major impetus to the search for alternative methods. In particular, the Montreal Protocol on Substances that Deplete the Ozone Layer, which came into effect in 1989 with 138 signatory countries and since 2005 has189 parties to the convention, has lead to the reduction in use of MB, with non-critical uses being entirely banned. Overall use in developed countries was reduced to 70% of the 1991 levels by 2003 ((PANNA) Pesticide Action Network North America 2004). Although the exemption for use of MB for quarantine purposes seems to be extended indefinitely, most developed countries continue to push for alternatives for this area as well.

Loss of commercial interest from product manufacturers due to increased requirements for registration or shrinking market gains, has also limited the use of some pesticides important to pest control, even when these particular products would have met all criteria for registration or re-registration.

Specific changes in the SIT are also a driving force for greater application of this alternative method. In previous decades, release of sterile tephritid fruit flies could result in additional damage to fruit from secondary bacteriological growth at the site of stings by females, despite their reproductive sterility (Aluja 1996). Now, for the Mediterranean fruit fly or Medfly (*Ceratitis capitata*), the use of genetic sex-linked traits facilitate the elimination of females during the production process (for a clear explanation, see Franz 2001 and 2005), which has resolved the objections to the releases. Before these advances in technology, both sexes of Medfly had to be irradiated, shipped and distributed, essentially wasting half of those costs.

With the advent of male-only releases of Medfly, the fruit damage from released females is avoided and costs are lower (Cáceres et al. 2004). A similar improvement in the technology of sexing other fruit fly species, for example *Anastrepha* spp., will bring similar reductions in costs for those species.

The use of artificial diets has progressed considerably for both fruit flies and screwworm. Considerable savings result from using alternatives to the fruit or full blood diets of the past. Waste from Medfly diet is being used as livestock feed, cutting down on the costs for waste treatment and the environmental costs of handling this waste stream. Before this shift to recycling, the Waimanalo, Hawaii, Medfly production facility produced 12 000 lbs (5.44 mt) of used diet and paid US$100 000 for its disposal each year (Wood 2000).

These and other technology advancements in SIT (e.g. see Sections 5.1 and 5.2) are a driving force for broader adoption of the approach for pest control. Many believe that the supply of sterile insects is now the primary limiting factor for that expansion.

2.2.3 Growing concern about pesticides

Public sentiment against excessive pesticide use has grown steadily throughout the world over the past decades. Concerns appear to be increasing most recently in developing countries, as globalization drives greater information access and improved standards of living allow communities to turn their attention to environmental issues. Over the past decade, international commitment to reducing pesticides (and other chemicals) in the environment was expressed by the adoption of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, the Rotterdam Convention on Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, and the Stockholm Convention on Persistent Organic Pollutants (or POPs Treaty) adoption of the international treaty to eliminate persistent organic pollutants, or POPs, (UNEP 2003).

One area of potential environmental impact is the contamination of ground water. This type of pesticide contamination poses special, prolonged harm due to the slow movement of groundwater. Recent studies in the USA revealed that many groundwater sources had been contaminated with dibromochloropropane (DBCP), now banned as a potent carcinogen but that was in common use in 1960s (EWG 2002). Even as recently as 2001, the Environmental Protection Agency (EPA) determined that in the USA the current uses for 41 pesticides were likely to result in water contamination that would threaten fish or their habitats. Thirteen of these pesticides were present in higher concentrations than those set to protect aquatic life in watersheds used by salmon. Contamination of this type will probably be revealed in a number of countries as requirements for water testing become more rigorous (Northwest Coalition for Alternatives to Pesticides 2001).

The development of resistance to pesticides is another concern related to on-going and extensive use. Any population of pests may contain individuals that are naturally more resistant to a pesticide than others. Under repeated use of the product, the individuals that have resistance are more likely to survive and reproduce. Hence, over time a naturally resistant population is selected for and the pesticide loses its effectiveness. Many pesticides have gradually lost their effectiveness due to the development of resistance in the target organism. In this situation, users often increase the amount and/or frequency of application of the pesticide, which can lead to the complete loss of effectiveness of the product. Rotation of pesticides that use different modes of action is recommended, along with the use of alternative approaches to pest problems. True resistance to SIT cannot develop, due to the manner in which it functions (see Iwahashi 1996, for comments on long term use of SIT). SIT is particularly useful for controlling species that have demonstrated pesticide resistance.

An additional concern about pesticides relates to the stockpiles of obsolete reserves that are not properly handled. A 2001 report jointly authored by FAO, the Organisation for Economic Cooperation and Development (OECD) and the United Nations Environment Programme (UNEP) (reported by PANNA 2001) estimated that more than 500 000 mt of old and unused pesticides are causing potential hazards to human health and the environment in developing countries and countries in transition. This estimate is five times that set by previous reports, indicating that stockpiles of obsolete pesticides (those that have been banned or expired) are an increasing problem. In fact, based on figures from the same report (Table 2.1), the total for world stockpiles will far exceed the half million mt level when the inventory is complete.

Table 2.1. Estimated world stockpiles of obsolete pesticides

Africa and the Near East	> 100 000 mt
Asia	> 200 000 mt
Eastern Europe and the Former Soviet Union	> 200 000 mt
Latin America*	> 30 000 mt

Source: (Davis 2000; PANNA 2001; * Environmental News Service 2005)

Obsolete pesticides are classed as hazardous waste and require special disposal, since by-products from the break down of some compounds are more dangerous than the original product. The FAO (Davis 2000) estimates the cost for proper disposal to be US$3/kg (or US$3000 per mt). In addition, much greater costs could be incurred to safely transport these pesticides to an appropriate disposal facility, which could increase the total disposal cost by an order of magnitude. Among the pesticides that cause concern when improperly disposed of are aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, malathion and parathion (PANNA 2001).

While the judicious use of pesticides will always be a necessity, communities around the world share growing concerns about overuse and mishandling of pesticides, and the resulting impacts on human health and the environment.

2.2.4 Increased awareness of the link between poverty, food production and the environment

Another driving force for change in approaches to pest control is the awareness that poverty cannot peacefully coexist with wealth in the context of globalization. In 1996, the World Food Summit (WFS) recognized that many people were still not receiving adequate nutrition on a daily basis. The focus of this FAO annual conference has shifted from simply food availability to poverty alleviation in the subsequent years, until the World Millennium Conference in 2000 set the target of reducing the proportion of people living in poverty by half by the year 2015. From 1970 to 2000, the proportion of undernourished rose from 38 to 40 percent of the least developed countries' population (Hendrichs 2001b). Estimates by FAO for 2002 indicate that 17% of the population in all developing regions is undernourished (UNSTATS 2005). Considering that over 40 percent of the world's population is under

20 years of age (UN 2000), adequate food production and distribution to people who can afford to buy the food will be a challenge beyond that optimistic time frame.

The link between food production and poverty is clarified further by noting that 70% of the world's poor live in rural areas and overwhelmingly depend on agriculture for both subsistence and income (World Bank 2005). The impact of cattle diseases, such as trypanosomiasis vectored by tsetse fly, is greater on the resource-poor herdsman than on more affluent livestock operations. The more affluent are able to obtain veterinary drugs to prevent or treat disease, use feedlots rather than moving animals to grazing areas that may be infested and to use varieties of cattle that provide the best yields but that may not show natural resistance to disease.

Human health is also a key factor in this interconnected web. A recent report predicted that additional spending of US$66 billion each year on health worldwide by the year 2015 would generate approximately US$360 billion in extra annual income (equivalent to 1 percent of the sum of the world's gross national product). Of this additional annual amount, US$38 billion will need to come from external aid by 2015. The belief that improvements in economic conditions will lead to improved health has been the basis for much international policy over the past two decades. This finding suggests that immediate and direct investment into improved healthcare is equally important to increased incomes, making increased assistance an issue of "security as well as morality" (Crooks and Dyer 2001, see also Pinstrup-Andersen 2001).

Overall trade (in terms of world exports) has increased tenfold since 1950 and sales by multinational firms exceed world exports by an increasing margin. In today's world, a single transnational telecommunications take-over resulted in a firm with value exceeding the gross domestic product (GDP) of almost half of the member countries of the United Nations (UN 2000). At the same time as this rapid expansion of trade, dissatisfaction with globalization, and its perceived impacts, is growing.

All of these factors have caused a shift in society's level of interest in the details of how food is produced and how public health is secured. Cited as the world's largest ever opinion poll (UN 2000), a 1999 survey of 57 000 adults in 60 countries concluded that two thirds of the population feel that their government has done too little to redress environmental problems in their country. This was particularly noted in developing countries. Means to achieve the fundamental global goals of reducing poverty and increasing access to food, while also reducing the impact on the environment, will be especially sought out in the coming decade.

All of these driving forces for change in pest control practices support the expansion of SIT whenever it is an appropriate option and available.

Section 3 Commercial issues for sterile insect production

3.1 Role of private sector in SIT

Throughout the over 50 years of use of SIT, the overwhelming majority of sterile insect production has been through government facilities and government programmes, even when considerable support for the SIT programme comes from the affected industry or community. The private sector has played a role as cooperator, funder or, in some cases, initiator of SIT programmes, as discussed further below.

3.1.1 Owners of SIT services

The most direct way for the private sector to participate in SIT programmes is as owners or shareholders in companies that are producing sterile insects or providing support services. This is a relatively new, but expanding approach that will have increasing impact on the commercialization of the technique.

There are both local and international private contractors that provide essential support to the SIT programmes, such as aerial release services. Production facilities may contract private services for support activities (e.g. security, maintenance or cleaning). All of the production facilities use private suppliers of diet ingredients, general supplies and equipment. More recently, private companies are providing support to the planning and implementation of SIT programmes. One example is described in Box 3.1.

There were some initiatives to form private companies and raise capital for proposed sterile insect production facilities (primarily for Medfly production) in previous decades. Yet none of these proposed large scale facilities were constructed at the time, and documentation regarding the initiatives and "lessons learned" is practically non-existent.

The past five years have witnessed a surge in private sector involvement in the production phase for SIT. A case study of the original plans for an early private-public partnership to build a pilot facility in the Republic of Slovakia (Novotny et al. 2001), appears in Annex 1, although that partnership was allowed to lapse with other funding options available. The private company that initiated this partnership, a limited liability company based in the United Kingdom, was formed to pursue a much wider involvement in sterile insect research and production. In deed, InSecta Ltd. (www.insecta.co.uk) was the lead partner for a recently-completed three-year, €2.5 million project to "enhance the utility of SIT" for the Mediterranean citrus crop (described further at www.cleanfruitsit.org).

A quasi-government facility in South Africa, the Infruitec Medfly Rearing Facility, operating since 1999, was fully privatized in 2003. This sterile Medfly small commercial facility began as a partnership between the Horticulture Business Division of the Agricultural Research Council (ARC) and the Deciduous Fruit Producers' Trust (DFPT) (Badenhorst 2001). Funds raised through a grower levy on export cartons of treated table grapes proved insufficient to cover all costs, and the partnership provided some support over those early years. The Western Cape Provincial Government has also provided small grants. The IAEA provided support totalling around R9 million (approximately US$1.2 million) in training, technical assistance and some specialized equipment over the past ten years. Without the planned expansion in production levels to benefit from the economy of scale, however, costs of the sterile Medfly have remained high. The programme also has not obtained government support to the degree expected. Therefore, in 2003, SIT Africa (Pty) Ltd was formed, with both founding partner bodies remaining as shareholders, taking over all sterile insect production and technical advisory capacity. This is the first fruit fly SIT programme in the world to have been privatized. Field releases have extended to three areas, with a total of approximately 18 000 ha of commercial fruit. Since 2004 all costs of production have been covered by the growers benefiting from the SIT, but financial viability of the operation continues to be precarious (Barnes 2007).

Box 3.1 A private services company to support implementation of SIT

A private company that was contracted to install and operate sterile fly release centers located in the Mexican states of Aguascalientes, Nayarit, Nuevo Leon, Sinaloa, Tamaulipas and Zacatecas, is expanding its services to include process control throughout the SIT field operations programme. Mubarqui Enterprises developed its own proven method for feeding adult Medflies during the time they are being held before release and offers a software program for daily use for managers of production facilities and release centers to follow the biological material throughout the mass rearing process and then on through shipping, reception, packing, emerging, chilling and release. This program also contains a trapping database to view in reports and digitalized maps weekly updates of wild and sterile fly distribution and abundance for all the working areas.

This decision support tool facilitates corrective actions, design strategies and preparation of reports. It would appear complementary to the financial tool developed for the Model Business Plan, as described in Section 7.

In addition, there is Mubarqui aerial release equipment that chills the adult flies using an integrated refrigeration system. The machine has a capacity to hold and release five million *Anastrepha ludens,* or nine million *Ceratitis capitata*. This machine is provided with sensors to monitor humidity, temperature and volume, and has an interface connected to a monitor in the aircraft panel, and also the company's purpose-developed computer system, as a source for the information which is transmitted as telemetric data. Using GSP data from the aircraft and the company's Macx program (www.macxd.org.mx), staff can see in real time what a plane is doing including: speed, bearing, tracking, altitude and also telemetric data from the biological or chemical load such as: temperature, humidity, volume, pressure, flow, swath and polygons.

In 2004 the first construction of a fully private sterile Medfly production facility began. Located in Israel, Bio-Fly Ltd., started pilot level production of sterile Medfly in 2005. The location, on kibbutz land, offered some discount to international prices. The biological product business experiences from a sister company, Bio-Bee Ltd. (which produces and markets beneficial insects and bumble bees as pollinators), should enhance Bio-Fly's potential for success. The company also enjoys a pre-existing market, as the Arava SIT project which had been running in Israel and Jordan since 1998 previously was supplied by sterile Medfly imported from El Pino, Guatemala.

In November 2005, the Bio-Fly facility achieved ISO 9001:2000 certification (certificate number 4806 issued by Institute of Quality and Control, Israel). There are plans to expand production and the current site has additional space for construction of the necessary additional buildings. As with SIT Africa, however, the current production capacity is limited.

The new Brazil facility for sterile fruit flies is publicly financed with resources from the Federal and Sate Governments. The project has established a number of strategic partmerships with several organizations (including the USDA, UNDP, national development agencies and universities) which will be cooperators in implementation, but will not invest directly in the facility. However, it is likely that when production starts the industry will absorb some of the costs through contributing levies.

Box 3.2 The first private sterile insect production commercial venture:
***de Groene Vlieg* company producing sterile onion fly**

Since 1981, the de Groene Vlieg company in the Netherlands has been mass rearing and sterilizing onion fly (*Delia antiqua*) for release for the purpose of suppression/control of that pest in commercial production areas. Onion fly is present throughout the region and eradication cannot be maintained easily. It is more economical to repeatedly release sterile onion fly than to create a quarantine barrier to monitor and control new invasions. Because the released flies do not disperse much beyond a particular field, unlike many species targeted using SIT, it has worked for this SIT service to be purchased on an individual grower basis.

As of 2005 the de Groene Vlieg facility capacity was over 400 million pupae per year, providing for treatment of nearly 4,000 ha of onions, which represents close to 20 percent of the Dutch onion production area (Loosjes 2000; pers comm. 2005). The area treated has been increasing an average by 5% per year and investment to increase rearing capacity has been secured. Releases are done weekly during growing season and adjusted based on monitoring and rapid feedback.

Challenges to the company include (Loosjes 2000):

- Density dependent character of SIT (does not work as well in high population density)
- Some farmers still feel more confident using more expensive pesticides
- Rotation of onion crops leads to redistribution of the pest population, rather than accumulation of benefits for the well managed fields
- Some loss of benefits to neighbours' fields
- Free riders in an area scheme (about 40 percent of the growers when reported by Loosjes 2000, but now decreasing).

The Dutch Government decommissioning of the irradiation source which was initially used by the company, forced them to send flies for sterilization in Belgium at greater cost and inconvenience. Such challenges noted above would also be faced by government-run SIT programmes, however, unless regulation or subsidies led to comprehensive coverage. In fact, while the operation is entirely private, the Dutch Government provided some support for the first two years as part of its promotion of environmental businesses scheme, but funding was not available beyond that point.

The unique positive contribution of SIT to the region, however, has been the reduction of pesticides used and continuing control of populations that had developed pesticide resistance. As pesticide resistance increases, the demand for SIT is likely to rise. The SIT approach for onion fly also has been below cost or competitive with costs of chemicals, except in extremely high populations when farmers chose SIT only after other measures failed. This suggests that the use of SIT for onion fly in the Netherlands could increase most rapidly if the government recognized the public benefit of this approach and maintained a policy that encouraged its early use by the individual farmers who are paying for the service. Direct support from the government also may be justifiable in response to the increase in pesticide resistance. In the meantime, national policies that restrict use of pesticides have provided a new impetus for growers to choose SIT in the Netherlands (Beek 2005).

3.1.2 Cooperators in implementation

One of the earliest uses of SIT was for the eradication of NWS in North America. This pest caused serious problems to the USA, primarily for the cattle industry since the 1800s. By the 1930s, livestock producers in the southeastern states were losing US$400 million annually due to the impact of the pest. In 1954, SIT was successfully used in a pilot programme to eradicate NWS from the island of Curaçao. In 1957, SIT was first used in Florida and by 1959 the NWS was eradicated from the entire southeastern USA. The focus of the programme shifted in 1962 to the Southwest where infestation rates were higher. By 1966 self-sustaining NWS populations were eradicated from the USA (see also Section 4.6; Hendrichs 1998).

The USA-Mexico Joint Commission for NWS was formed in 1972. In 1976, a production facility with a capacity for 500 million sterile flies per week began operations in Chiapas, Mexico. Mexico was declared free of screwworm in 1991, Belize and Guatemala in 1994, El Salvador in 1995 and Honduras in 1996. Nicaragua and Costa Rica were declared free of NWS in 2000. Panama is expected to receive this status in 2002. To ensure sustainability of the pest free status, monitoring activities, including inspection of animals, must continue on a permanent basis. Outbreaks that occur through new introductions (e.g. with the import of an infested animal) require the implementation of an emergency plan that includes monitoring and control. A new facility will be opened in Panama to maintain a barrier of sterile flies at the Darien Strait. The cattle industry has been central to the continuing support for these programmes[4] (Sheesley et al. 2001).

Presently the Government of Jamaica and the Jamaican Livestock Association are working to eradicate screwworm from that island country. Losses to the cattle industry and impacts on public health were considered in the context of a benefit cost analysis (see Section 4.6.1). The flip side of a private sector group cooperating in the implementation is that their support only goes as far as their personal benefits. The National Cattlemen and Beef Association (NCBA) of the USA are great supporters of the NWS eradication programme, including its extension to the Caribbean as that would provide another natural buffer to possible reintroduction to the US. This American group does not support using US funds for South American programmes, however (Sheesley et al. 2001).

The pink bollworm (PBW) control programme in the southwestern USA is another example of cooperation between government and private sector. The PBW is an introduced pest and heavily reliant on cotton as a host. Because the larval stage of the PBW lives inside the cotton boll, insecticides are not highly effective. Short growing seasons achieved some control in the Imperial Valley of California, reducing the population in targeted areas so that suppression using SIT and genetically engineered cotton may be possible. Releases began on a large scale in 1970 in the San Joaquin Valley of California. Sterile PBW adults are supplied by a USDA rearing facility in Phoenix, Arizona (Walters et al. 2000). In this case USDA and California Department of Food and Agriculture (CDFA) have formed a successful working relationship with the California Cotton Pest Control Board. The cooperation of the affected private sector is not surprising considering the benefits derived from these area-wide SIT programmes.

[4] It is interesting to note that with the announcement of eradication from the USA, the NWS became an exotic pest and all costs for further control of outbreaks fell entirely on the federal government. Prior to that declaration in 1966, a cost sharing programme with the states bordering Mexico was financed 50 percent by the federal government, 25 percent by state governments and 25 percent by industry (Klassen 2000).

3.1.3 Private sources of financing public projects

In recent years, there is a trend for government agencies related to plant health to secure reimbursement for services (e.g. National Plant Board 1999; Mumford et al. 2001; New Zealand Institute of Economic Research 2000; Nugent et al. 2001, Quinlan and Enkerlin 2003). In light of this, the trend in more developed countries will be for funding of SIT activities to come from the affected public (e.g. for urban based programmes) or the private sector, whether directly based (e.g. levies per box of fruit exported) or through charging of taxes by the relevant government agencies. It will be easier to secure this funding if the private companies were paying for the full costs of pesticide use prior to the implementation of SIT (e.g. compare case studies in Annex 2 and 3).

The Okanagan-Kootenay Sterile Insect Release (SIR) Program is a successful initiative using sterile codling moth to reduce damage to commercial orchards and their surrounding areas in the fruit growing areas of Okanagan, Similkameen, Creston and Shuswap Valleys of British Colombia, Canada. The SIR Program is a community effort, involving local, regional and national government, the tree fruit industry, growers and property owners. In order to achieve consistent suppression, all owners of non-commercial and urban properties with apple, crabapple, pear and flowering quince trees in the control zones are asked to comply with SIR regulations. The federal and provincial governments paid the approximately US$6.73[5] million capital costs for construction and equipping of the rearing facility in Osoyoos (Bloem and Bloem 2000). Homeowners throughout the treatment areas pay a small tax based on the land value of their properties and commercial growers pay a parcel tax per acre of apple and pear production. Each "parcel" of property that is greater than 0.3 acres (0.15 ha) with 20 or more codling moth host trees on it (apple, pear, crabapple, quince) is levied the tax (OKSIR 2001).

The area is calculated on the drip canopy area of the fruit tree blocks, the minimum levy is for one acre (0.4 ha) of land. Even trees that have been cut down but not uprooted are considered hosts and are subject to taxation. On areas of and where trees are not planted in blocks (e.g. on golf courses, parks) the tax is calculated using the formula: number of acres – number of trees/100. There are also concessions for orchards that are interplanted with other non-host plants. This programme has been unusual in its broad base of support and direct levy for obtaining financing (OKSIR 2001).

Obligatory municipality-based and locally funded Medfly control programmes in Western Australia were abandoned over time but have received renewed interest with the increasing concern about pesticide use near residential areas (Mumford et al. 2001).

There are many who feel that public funding must be part of all SIT programmes to achieve success (Gardiner 2005). Creative financing mechanisms for the initial high-cost period of an SIT programme that produces (versus purchasing) sterile insects should be sought. Some ideas are described in Section 3.2.2. The Cleanfruit project is summarising other approaches to funding of SIT programmes, and will report in early 2007 on findings (www.cleanfruitsit.org). Section 7 of this report discusses issues related to financing the unique business of SIT.

[5] In terms of exchange rate at that time; Canadian $7.7 was approved for capital costs and the project came in Cnd $300,000 under budget.

3.1.4 Private sector as a generator of development

Although development assistance is generally not the goal of private business, the importance of development for increasing new markets is not lost on business planners. There is also an increasing sense that business should return some of its profits to society at large. In addition to the moral dimension of this outlook, global and local security depends on it (see also Section 2.2.4).

Investment capital is often closely tied with technology transfer and technological innovation is spurred by global capital flows (Juma 1999). The value of Foreign Direct Investment (FDI) in most developing countries has overtaken overseas development assistance (ODA) as a source for economic growth. The world total for FDI[6] flows rose a dramatic 646 percent between 1992 and 2000, from 79.1 billion ECU[7] to 590.1 billion ECU (Eurostat 2001). The total flow from the EU increased 1610 percent over the same period. By the end of 2000, more than 50 percent of total world FDI originated in the European Union (EU); less than 10 percent from the USA and 6 percent from Japan (Eurostat 2001). The other countries of the world contribute a vast amount of FDI in real terms, equivalent to 192.4 billion ECU in 2000.

The improved ratio of FDI over ODA is due to decreasing ODA as well as increased flows of FDI. Net inflows of FDI to Sub-Saharan Africa increased from a proportion of –0.1 to 4.6 from 1990 to 1998. Over the same time, net ODA across Africa dropped from US$32 to US$19 per capita. The conclusion of some donors is that aid is not sufficiently effective for economic growth. In the past, donors may have even relied on their own institutions to implement the programmes when accountability in the government appeared weak, further eroding governmental capacity. Aid dependence, closely tied with heavy indebtedness, demands a new approach involving the private sector for future projects to succeed (IDA 2000).

Besides private business, private foundations or trusts may be the source of FDI. This type of investor may be easier to attract to public health projects that clearly provide public good but are considered high risk.

3.1.5 Conclusion

The examples highlighted above show the overlap among roles of the private sector as cooperator, funder and initiator of SIT programmes. There is also a gradation from broad based public sector financial support that is historically obligatory, to private business support due to the well-identified interests of a particular industry. Finally, the contribution of the private sector, including private charitable foundations, to economic development is considered in general terms.

The role of the private sector as participants in the ownership of sterile insect production facilities is a new one. All indications from the historical perspective is that this and other roles will be taken on successfully by the private sector as SIT becomes more cost effective and familiar to producers.

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[6] This consists of foreign direct investment and excludes reinvested earnings and intra-EU flows. The largest recipients of FDI are the USA (over 48 percent of world total), the EU (over 20 percent) and Japan (less than 2 percent). The UK remains the largest recipient of FDI in Europe, although its lead has diminished in 2001 (IPAnet 2001). The remaining amount of inflows still exceeds 171 billion ECU (Eurostat 2001).

[7] The European currency unit (ECU) was initiated in 1979 as an accounting unit internal to the EU. It was the precursor to the euro (€), which was introduced January 1, 1999. The method for calculating the ECU at any given time in relation to other currencies is explained at the exchange rate service web site: http://pacific.commerce.ubc.ca/xr/ECU.html

3.2 Guidance on organization of a production business

3.2.1 Choices in structure of a business

A business may be set up as a legal entity in the form of a corporation or limited liability company. A joint venture or partnership may also be set up as a legal entity, or in the form of a corporation, expressing the partnership in terms of stock ownership. In the case of sterile insect facilities, the advantage of government participation in a joint venture, partnership or stock-issuing company is the existing relationship between member country governments and the IAEA (see Table 3.2 at the end of Section 3 for a list of members), which remains an important source of training and technical assistance.

Under current IAEA policy a facility that is government owned, even with private participation or subsequent buy out, qualifies for IAEA programmes as long as the country where it is located is a member country (listed in Table 3.2). The involvement of the country's government will facilitate the support of IAEA's technical resources, including training of staff, assistance in the facility design, exchange with other production facilities, supply of insects to initiate a breeding colony, and possibly funding for research programmes. This same relationship with IAEA may be achieved through partial ownership by an IAEA member government.

A government might start a SIT facility with the intention of being bought out by private investors within a specific time frame or at the point of a predetermined production milestone. This scenario, similar to the Fundación Chile[8], offers an interesting alternative or complement to 100 percent private investment and recognizes the public good that may be incurred from such a facility. Another model for this approach could be the Commonwealth Development Corporation of the UK, a quasi-governmental corporation set up to invest in beneficial but high-risk projects in transition economies. Many of the Commonwealth Development Corporation projects include an aspect of sustainable use of natural resources. The Commonwealth Development Corporation itself is converted to a private partnership in 2002. This transition is made easier by the fact that they have run all of their investments as businesses, rather than as ODA or donation schemes.

The key element of the assisted start up model is that the investment be made for viable projects that are capable of generating profit and outlasting the assistance phase.

If funding for a production facility came from a non-governmental organization (NGO), private foundation or donor, it may be preferable that this funding group is partial owner of the facility. This is particularly true if the financial support is to be used to attract additional funding from banks or private investors. In fact, passive investors are impressed whenever the people directly affected by the success or failure of the business are also investors, either the management team, employees or other active investors. Foundations, donors or NGOs are likely to provide other support such as assistance in business planning or management training that would supplement the financial support. Unfortunately, these types of organizations are unlikely to seek direct ownership, unless through a programme designed for that purpose as mentioned above.

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[8] Since 1984, Fundación Chile has created 36 companies, 17 of which have been transferred to the private sector (Fundación Chile 2001). By taking the initial risk of starting up businesses using new technologies, this model encourages innovation and has contributed significantly to the Chilean economy. The capital gained by sells of the businesses goes back into the same objectives.

Whatever the arrangement, ownership of a business may be structured by using two types of stock: common and preferred. Common stock will generally go to the original founders and, through a stock option programme, employees of a company in the start up years. This type of stock recognizes the additional efforts (often beyond the level of compensation) of a start up team and provides motivation for performance. Gains by the business may then be passed on to these common stockholders. Common stock may be issued at a lower cost per share so that employees, for example, will not have large tax ramifications from receipt of stock. The expectation is that the value will grow and there will be a demand in the future that provides a market for the shares and sets a higher price.

Preferred stock can be used for investors. The value of these shares is often set at 10 times the value of common stock (Engel 2001a). Since this group is purchasing their stock with cash, the higher value protects them from the perspective of taxes as well. Investors will normally require some preferred rights to go with their stock. These may include representation on the Board of Directors, first right of refusal on future sell of the business or additional shares and non-dilution clauses. At the time of an initial public offering of stock in the company, both types of shares are converted to common stock (Engel 2001a).

The founders of such a business will want to retain the greatest ownership possible in the early stages. Outside investment should be limited to 35 to 40 percent for initial start up funds. When further funding is sought, the value of the overall business will be greater so that the percentage will continue to remain below 50 percent even though the actual capital values increase (Engel 2001b). The objective of building a business is not necessarily to maintain controlling ownership in the long term, however. At the time of a public offering founders might still retain typically a maximum of 20 percent, with an additional 20 percent owned by management and employees and the rest of the stock owned by the start up investors (Engel 2001b).

3.2.2 Options for financing

There is little experience to draw on regarding financing for privately-owned or operated sterile insect production facilities, although private funds are often collected for government-run programmes (see 3.1.2). Therefore, in this section general information is presented for consideration by private companies when seeking financing of such a facility.

There are two basic approaches to financing any new business: **Equity Financing or Debt Financing.** It is easier to attract financing as it shifts away from full equity financing, in this case possibly venture capital of high risk, towards debt servicing for an already guaranteed market. This type of project is not likely to reach the debt end of the spectrum for all costs and will probably remain in an equity situation. Investors will be impressed by contracts for the product, but then so will a bank. If the company has substantial and reliable contracts for purchase of the product, it may be best to seek financing from a bank that will not own any of the company when the loan is paid off.

Methods for raising capital — ranging from the highest risk, total equity funding, to the most conservative, debt financing — are presented below.

Venture capital

Venture capitalists may finance a project as small as US$5 million (AllBusiness 2001a) but most investment brokers or venture capital organizations will not work with projects under

US$10 million. Even the less expensive groups for raising venture capital (e.g. Cosco Capital, based in New York City) require a 6 percent fee of any money raised and a monthly fee of US$7500 during fund raising (S. Hammons, pers. comm 2001). Other groups require more. Pure venture capital will be more expensive to obtain, as the higher risk makes capital harder to obtain.

Smaller amounts around US$1 million can be obtained from "angel" investors or private financiers who are willing to take more risk and receive less profit than most venture capitalists. The estimated 400 000 angel investors in the USA invested around US$25 million in 23 companies in 2000. A smaller SIT production facility could begin with this approach, but if no further source of capital is identified, this will only create bottlenecks and failed start ups (Powell 2001).

Venture capitalists will generally expect to receive preferred stock with terms that will provide a financial advantage in the case of liquidation or a merger (AllBusiness 2001b). This stock will be convertible under predefined situations, including in the case of an initial public offering. Venture capital may be invested as a sum total, but often will be phased in as established milestones are reached by the business. If these milestones are realistic and obtainable, this is a useful mechanism for the business managers to be assured of future funding to match the results.

On the short term, venture capital investments in the USA fell from US$26.1 billion to US$10.2 billion from the first quarter 2000 to the first quarter 2001 (Powell 2001). Any predictions for a downturn in the economy and or terrorism fears will only further this downward trend. For example, seed financing was reported to be down 75 percent in the same PricewatershouseCoopers/Venture One survey conducted earlier in 2001 (Powell 2001).

Government or Corporate Bonds

Any group may issue bonds. Corporate bonds are similar to those issued by government, but are of higher risk for most situations. The level of risk of the bonds influences the value and the interest from buyers.

The obligatory levy approach is used for the codling moth control in Canada, as described in Section 3.1.2.

Sell of outtake

Energy generating plants were able to operate on the "sell of outtake" and this concept could be applied creatively to a sterile insect production facility. This is essentially what was done by the California Department of Food and Agriculture (CDFA) when it financed some of the costs for equipping the Metapa plant in Mexico under the agreement that California would receive a certain amount of production if an outbreak should occur.

Sell of outtake implies an initial investment at the time of construction and equipping so that the loan burden on the private firm will be less and incentives to enter into the business greater. By providing a guaranteed buyer in advance, the risk is greatly reduced and other types of financing will be more easily obtained. This approach is another way in which the IAEA can support private business that is interested in providing backup facilities/colonies of sterile insects for public health programmes (i.e. tsetse). Since market conditions will not provide a secure market at this phase of development, some up front financing in exchange for subsequent outtake will help private businesses gain financing from other sources as well.

Bank loan
Businesses seeking US$100 000 or less may obtain it through a bank loan using collateral from the owners' personal assets (AllBusiness 2001b). Generally, a more substantial bank loan requires such a large amount of collateral that it is difficult for the type of businesses that would be created for SIT. On the other hand, if there are existing contracts that would serve as collateral, then debt financing through a commercial bank is relatively simple.

Unlike for some industries, SIT is not likely to have buildings and equipment that have much value on the open market if the business did fail (see Section 3.3.3 on appraisal). Production facilities may be located in less expensive or even remote areas (see Sections 3.3.1 and 3.3.2 on selecting a location). Used equipment and the design of the facility may not be readily suitable to other businesses for resale.

Donor funds or guarantees
Funds from multilateral, regional or bilateral economic development organizations are the least risk to the company and may even be in the form of grants, requiring no repayment. Other sources include regional development banks and bilateral donor or loan programmes.

An important source of potential funding for projects throughout the world is the multilateral World Bank Group. The World Bank Group includes:

- **International Bank for Reconstruction and Development** (IBRD) which provides loans and development assistance to middle-income and creditworthy poorer countries;

and the

- **International Development Association** (IDA), which together with the IBRD are commonly referred to as "the World Bank";
- **International Finance Corporation** (IFC), which works exclusively with projects in the private sector;
- The **Multilateral Investment Guarantee Agency** (MIGA), which is described in Section 3.5 on insurance; and
- **The International Centre for Settlement of International Disputes** (ICSID) – described below.

The IFC provides around 25 percent of total financing to suitable "for-profit" private sector projects in developing countries. The financing is in the form of loans and equity and through intermediary financing by supporting underwriting, securitization, investment funds and other approaches. The IFC lends at market terms, but provides greater technical assistance and knowledge of developing countries than many private lenders, along with the influence of the World Bank Group. Small to medium enterprises (SME) can receive from US$100 000 to US$1 million in funding through the IFC.

The IFC also has a funding designated for Sustainable Agriculture and Forestry projects and for Biodiversity projects. These are aimed at using "production methods that can contribute to the long-term protection of natural resources" and "commercially viable activities that contribute to conservation of biological diversity in developing countries" (IFC 2001). Although this has been expressed through projects such as organic certification of a production site, it is possible that SIT projects would qualify under these criteria. This is particularly true if the use of SIT could replace some use of pesticides near a fragile or protected area.

When appropriate to the use of SIT, the presentation of the SIT programme as an environmental project, rather than only an agricultural one, could make financing easier. For example, under the European Commission's financing mechanism of the European Community Investment Partners (ECIP), projects classified in the agriculture sector dropped from 23 percent to 5 percent of the allocation from 1986 to 1998, while the allocation for environmental projects was introduced in that period and rose in percentage. Environmental project contributions through ECIP were still lower in real terms, but environment is now emphasized as a priority in the criteria (European Commission, 2001).

Finally, some failure of start up businesses simply must be anticipated. The ECIP programme has calculated that 19 percent of all the feasibility studies for a new small to medium size business actually lead to a joint venture, and only around 20 percent of those that go forward succeed. An evaluation of the programme confirmed that the framework for reviewing loans caused investors or financial institutions to make more measured responses and rational decisions about loans than they would have without participating in that process.

Comments on options

Unless the start up company goes public or is acquired, the investor will have a hard time getting his or her money back in a time frame that suits most investors. Venture capitalists generally want to cash out of an investment in 3 to 5 years (AllBusiness 2001a).

Other investors may be willing to leave their capital tied up for a longer time frame, but will expect a minimum level of dividends or interest payments in lieu of the faster turn around of capital. In this case, investors look for sustainability. Their view of this will be based to a large degree on the credibility of the owners and the management team.

The pesticide industry may be viewed as both a competitor with and a potential future owner of a sterile insect production facility. At the present time, most pesticide manufacturers have not felt much impact from loss of sales due to use of SIT (E. Johnson, pers comm 2001). As this changes, these companies may resist the uptake of the alternative technology, offering discounts or disputing the efficacy of the SIT. In the long term, however, these same companies may be the future owners of a production facility, just as they have bought out some of the biotechnology start up businesses once the commercial value of their product was proven (Enkerlin 2005).

Regardless of the source of financing, technical assistance offered by the IAEA will continue to be crucial to the success of SIT programmes and sterile insect productions facilities.

While the IAEA supports research and training, the link to business development could be strengthened. Without an intentional involvement in business start up, the IAEA may in fact thwart competition and thereby discourage the use of the very technology it has worked so hard to improve. IAEA Member States that request assistance for adoption and use of SIT must be fully committed, be aware of the long-term nature of these projects and have a strong sense of ownership. Lack of these conditions would result in poor uptake of SIT in the long term.

3.2.3 Organizational structure

Personnel at production facilities are "the most important part of the process and the most likely cause of failures" (Calkins et al. 1996).

The management team for a sterile insect facility will need to consider how to achieve the following from the development phase through to continuing implementation:

- providing security and maintenance of the rearing facility;
- general administrative and personnel management services;
- services to acquire, deliver, account and control for all critical materials, supplies, equipment, replacement parts for the constant operation of the facility 24 hrs/day, 365 days/year;
- financial and property management services, including budgets, accounts, inventories, reports and audits.

Furthermore, there will be the need for a management team to undertake the responsibilities for general management, marketing, legislative and public affairs, and possibly pest risk analysis and new project/product development.

Most fundamental to the business, however, is staff experience in sterile insect production, methods and product development, field activities (possibly both suppression and eradication activities), sterile insect release (including aviation services and related technologies) and quality control (production and field), including ensuring the appropriate rearing criteria are met. Insect monitoring (e.g. mark-release-recapture techniques) and data collection and management (to be analysed for scientific/cost benefits) could be important for demonstrating the value of the product and supporting customer satisfaction.

There is no single approach to organizational structure for a sterile insect production facility. One generic model is presented in Figure 3.1. Dyck et al. (2005b) describes the role and style of management and programme staff in more detail.

Chief Executive Officer and Project or Species Manager

In this generic organizational chart, a Chief Executive Officer (CEO) is the person with overall vision of the business, capable of both marketing and scientific/technical management skills. The CEO should be aware of potential threats and competition to the business and have a strategic plan for capitalizing on strengths and opportunities. He or she should develop an overall business plan including measurable performance indicators, monitor the success of the business in meeting these milestones and make adjustments to the operations as needed.

This person, who may be off site or involved in other businesses, depending on the size of the operation, will coordinate closely with the Facility Manager who is the on-site management.

Companies with more than one species or those handling large scale projects, often in various countries, may also require a Project and/or Species Manager to interact more closely with those customers. This may be similar to an account representative who tracks the status of each contract in other types of business, or it may be a highly experienced SIT programme manager who is in place to anticipate and help to resolve issues that arise with any field programme. Market research and development of new customers may fall to this individual, or be handled by the CEO in the case of smaller companies. It is also possible to hire in this expertise, but care should be taken to maintain some institutional memory when market research is not in-house in order to avoid costly duplication of efforts over the years.

Production Company Organizational Chart

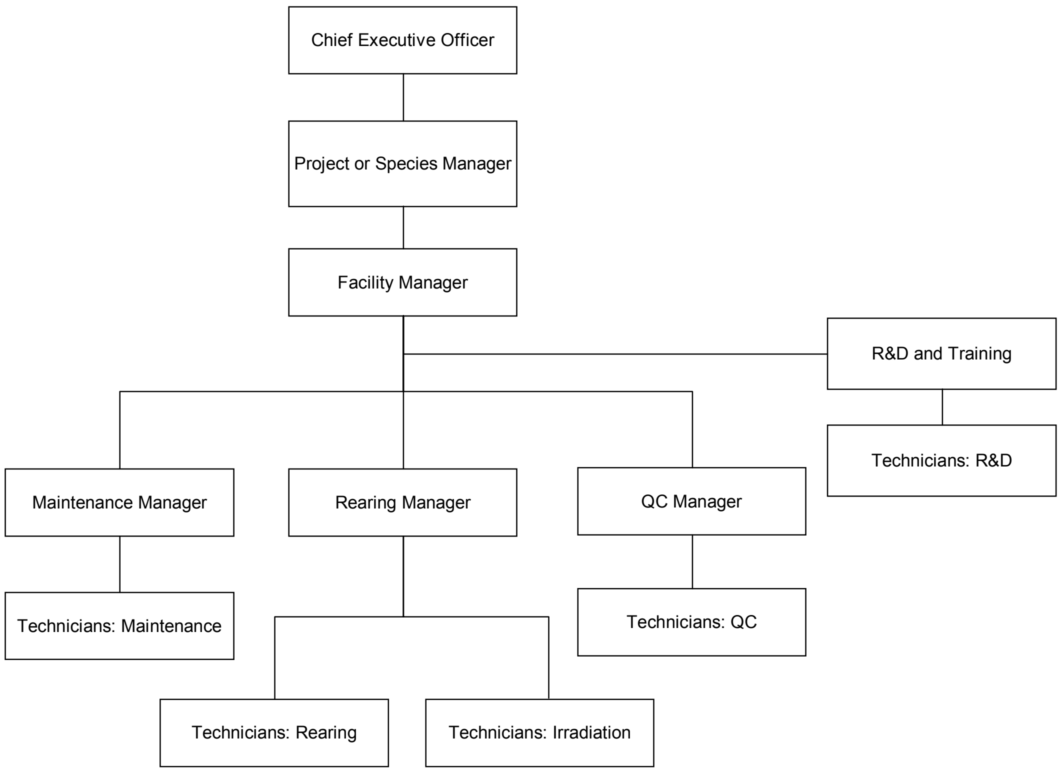

FIG. 3.1 Generic organizational chart for a sterile insect production company.

Facility Manager

The Facility Manager is generally the highest level management on site and is the person responsible for maintaining high quality production to the level matching contracted or projected levels needed to supply the customers. This person will oversee logistics and compliance with all regulations or norms related to the production facility, which may include:

- field collection or purchase/import of the initial colony;
- compliance with quarantine measures on site and for import/export;
- issuing requests for tenders, purchase, arrival and storage of all inputs;
- ensuring maintenance of all the facilities, including laboratories;
- scheduling and organizing routine cleaning or maintenance of modules;
- transport of the sterilized insects to a release centre.

This may be the person in charge of worker relations and health and safety on site. The Facility Manager will also direct the Research and Development (R&D) and training to best support the overall goals of the company and the retention of existing customers. The Facility Manager will also be interacting with the CEO and/or Project or Species Manager to identify new products to attract customers, whether this is a new species or strain, a new delivery system, an improvement in performance or other product innovation.

Mass Rearing and Quality Control Manager(s)
This level of manager is exclusively concerned with coordinating and controlling production to ensure maintenance of quantity and quality. Furthermore, his responsibilities extend to the quality of service provided by the business to the client. The position requires the supervision of a number of mass rearing and quality control (QC) technicians (number to be decided based on the size of the production facility).

In some companies a Mass Rearing Manager will be a separate position in charge of all production. In situations with more than one species or modules, there may be more than one Rearing Manager. This position is essentially a foreman's role, supervising and managing the rearing technicians (possibly to include training) and coordinating with other levels of management to ensure smooth operation and timely delivery of the product.

Rearing Technicians
The Rearing Technicians are under supervision by the Rearing Manager or an overall Production and QC Manager. The duties of the Rearing Technicians vary according to the species being mass reared, but generally consist of all daily operations of the colony maintenance, management of the filter colony, diet preparation, egg seeding the production trays, transfer of pupae or adults for the sterilization process and cleaning of the rearing areas.

Quality Control Technicians
The QC Technicians are under supervision by the QC Manager and have responsibility for sterile insect quality (diet ingredients, production processes and field performance of the insect). A QC Technician may be involved in the field release (including aerial release) to ensure proper use of technologies chosen.

Irradiation Technician
The Irradiation Technician generally reports to the Rearing Manager. In most situations, a specific position of Irradiation Technician is required in order to carry out the sterilization process. This person should have an official license to operate the irradiation facility. The facility would need to formally appoint or duly authorize a single person, who was suitably qualified and experienced to run an irradiation facility. This person needs theoretical and practical knowledge of basic nuclear physics, radiation physics and radiation protection. Minimum qualifications would be a first degree in a related discipline. The Irradiation Technician manages a structured system of maintenance and testing of the system. Another responsibility is to set up an Emergency Plan for such a system. This position may be supported by an independent Radiation Protection Advisor and a locally based Radiation Protection Supervisor. In some situations deemed lower risk, requirements may be less stringent, for example in the case of some self-contained irradiators such as the Gamma Cell 220.

Irradiation facilities are periodically supervised by the company that supplied the source. Every facility has standard operating procedures to assure proper and safe operation.

Research and Development Division
Research and Development (R&D) may be conducted by a specialized staff of the company or supplied in cooperation with a university, research centre or even another private company.

The common denominator will be that all R&D is application oriented and aimed at improving the success of the business in some concrete way.

Government facilities have not always included R&D in their operations, yet government research centres were available to support the programme. Most experienced facility managers feel that more attention should be given to the R&D component when developing new facilities, especially in the private sector (P. Gomes, pers comm 2002).

Field staff
Depending on the organization of the company, an SIT programme may be supported in the field phase as well the production phase. Insect surveys to determine population levels and distribution, contracted pilots for aerial release or other positions may be provided by or through the private sterile insect facility. It is also possible, however, that the customer provides all of this side of the programme.

The important thing is to agree on what is provided by the company and the company is responsible to deliver. This is discussed further in Section 3.7.1.

3.3 Factors to consider when choosing a production site

3.3.1 Country selection for production facilities

Investors may already have preferences for the location of a new production facility for sterile insects. For those who are not tied to a particular country, professional advisory services offer analysis of alternative country locations. Even if investors are already committed to a particular country, review of these criteria will help to identify strengths and weaknesses of the location.

Points to consider, in approximate order of priority, include:

- costs of land acquisition, construction and operation of a production facility;
- proximity to markets;
- availability of appropriate sites (necessary attributes discussed in 3.3.2);
- transport system for land or air cargo;
- availability of a work force that can be trained in the necessary skills;
- political stability of the country;
- levels/types of crime;
- risk of natural disasters (see more on climatic/geological factors below);
- absence or presence of the insect to be produced, regulations regarding its entry and transport from the facility;
- vulnerability of the location to the escape of the species produced (in balance with the proximity of market issue);
- approval or even support from the country government for this activity;
- acceptance by the surrounding population of this technology.

Each of these points is important and is discussed in this report.

Primary among these is the cost of construction and operation of a facility. This is the topic of Section 7. The model presented in that Section for a large Medfly production facility shows that labour rates comprise one of the highest levels of sensitivity for the overall result, second only to insect diet. A large portion of the labour is minimum wage in most facilities. Table 3.1 shows a comparison of minimum wage in selected countries.

Table 3.1. Worldwide comparisons of minimum wages, based on hourly rates

Country	Minimum wage (Euros)	Country	Minimum wage (Euros)
EU		**South America**	
Luxembourg	8.42	Argentina	1.38
Netherlands	7.49	Chile	1.09
Belgium	7.45	Peru	0.80
France	7.61	Columbia	0.77
UK	6.17	Brazil	0.63
Ireland	7.65	**North America**	
Italy	6.41	USA	4.30
Finland	5.39	**Asia Pacific**	
Greece	3.69	Australia	7.51
Portugal	2.25	Japan	5.57
Spain	3.08	New Zealand	5.35
Eastern Europe		Taiwan	3.15
Poland	1.25	South Korea	1.59
Hungary	1.29	Vietnam	0.22
Czech Republic*	1.41	Source: http://en.wikipedia.org/wiki/Minimum_wage#Worldwide_minimum_wages [last accessed 17/11/2005]	
Romania	0.55		
Bulgaria	0.46		
Slovenia*	2.94		
Ukraine	0.15		
Russia	0.12	* Source: http://epp.eurostat.cec.eu.int/portal/page?_pageid=2053,47645761&_dad=portal&_schema=PORTAL [Last accessed 21/11/2005]	

Proximity to markets is important since the quality and viability of the product depends on prompt delivery of the sterile insects for release, especially for certain species. Delivery must be within 40 hours for Medfly to prevent damage from hypoxia. Yet, sterile Medflies have been shipped long distances with success; the other reason proximity is important is to achieve lower transport costs.

Political risk is another significant factor in many countries that would otherwise be ideal for this industry. Political risk may consist of transfer restriction (the inability to convert local currency to foreign exchange), expropriation by the host government, breach of contract by a government and loss of business or assets due to war or civil unrest (e.g. MIGA 2001). Breach of contract by a private entity is not generally considered a political risk, but rather a commercial risk.

There are various services for determining political risk. The Economist's Economic Intelligence Unit is one example. Several donors or investment guarantee groups also provide information on the political risk of various countries.

In addition to these criteria, other subjective criteria to consider may be those captured in the Human Development Index, developed by the UNDP, and their complementary Human Poverty Index. Although these cannot be compared across years due to changes in criteria, countries and regions can be compared with each other in the same year's evaluation (UNDP 2001). Other indicators look at data such as the inequality of income within a country. In a perfectly equal situation, the index is 0. Slovakia, for example, is the lowest (closest to equitable) of the Eastern European and Commonwealth of Independent States (CIS) countries, since many have experienced a large increase in inequality since the move to market economy. One can interpret that as a good thing, but at the same time one should ask if the country is primed for a similar shift to more unequal incomes and if this would impact a project (UNDP 2001).

Ultimately, if the potential buyers for the sterile insects are involved (directly or as tax payers) in the investment for construction, they will determine the country of production.

3.3.2 Specific site selection

The availability of existing property, often with some infrastructure, that may be adapted to this use has influenced specific site selection in several cases. A former sugar cane processing facility near Pacoro, Panama, for example, has been renovated and expanded significantly to house both sterile NWS production and research facilities. This new facility will supply the permanent barrier releases along the Darien Strait and the Colombia/Panama border, as well as other USDA-cooperator programmes over time. This barrier between the Panamanian Isthmus and northern South America must be maintained, along with sufficient supply to control any outbreaks in North America, until such time as the NWS is eradicated from the Western Hemisphere. While there is interest in eradication in some areas, continental eradication in South America is unlikely at this time so the future demand for sterile NWS is reasonably secure.

The new fruit fly production facility in Brazil is located at a government-owned site, incorporating existing buildings with new purpose built structures. The proposal from Slovakia reviewed in Annex 1 also utilized a government-owned existing property. In other cases, however, a specific site may not be limited to government-owned properties, and in these cases the criteria discussed here should be applied.

Only sites of adequate size for all future expansion plans and of an affordable cost should be subjected to additional criteria. Any site for a production facility will need a minimum level of infrastructure in order for someone to successfully do business. These minimum requirements include:

Physical infrastructure

- access to affordable and steady supply electricity;
- good quality water supply;
- water treatment options;
- road systems;
- access to airport (if air shipment will be used);
- reliable telecommunications services, including internet access;
- local availability of most inputs (original construction and on-going inputs such as diets for production).

Factors considered when selecting the country are also relevant, in more detail, to the site selection. In addition to the physical infrastructure, these criteria include social/political and legislative attributes.

Social attributes

- proximity of an appropriate work force;
- absence of labour disputes in similar sectors;
- near a university for access to student labour, if work is seasonal or part time;
- near research facilities if possible;
- overall safety of the area (in regard to crime);
- absence of political unrest.

Legislative attributes

- clear land ownership system;
- favourable tax structures and clear investment laws;
- transparent regulation of intellectual property rights;
- incentives for investment;
- uncomplicated system for permits on buildings, zoning issues, or licenses.

From the perspective of future value of the location, the project site selection should begin with a thorough consideration of factors that might lead to economic depreciation (or appreciation). Next, a professional appraisal of the site and the proposed improvements will inform investors of future options for disposing of the site. As far as possible the improvements for this highly specialized business should be as generally adaptable to other businesses as possible. This adaptability will increase the possible demand or market for the property should it ever become desirable to sell it. Second, the widened marketability will give investors and lenders more confidence by lowering the risk of non-liquidity of the asset.

The most reliable appraisal technique is the comparable sales method because it relies directly on market activity to determine Market Value. Equally important for site selection is the consideration of a component of the Replacement Method – Economic or External Depreciation. Here the investors must consider both present and future market value. Appraisal of such a facility is discussed in more detail in Section 3.3.3.

A sterile insect production facility has other requirements as well. Biosecurity concerns will need to be considered using the following criteria when the species under production is not already established in the area:

Bioecological attributes

- ability of any exotic or endemic species under production to establish in the environment free of the pest, in the case of an escape (seasonal limitations on survival, host limitations);
- effectiveness of monitoring tools that can establish if any escapes occur;
- availability of tools for control of an escape leading to an outbreak.

This would relate to climatic/geological traits (Sheesley et al. 2001) that would lower the risk of escape including:

- minimum tornado activity;
- minimum hurricane activity;
- minimum seismic and volcanic activity;
- outside of flood zones;
- outside of areas prone to forest or bush fires;
- other common sense traits related to natural disasters in the area.

Biosecurity plans are discussed under Section 5.3.3. The entire list of criteria for site selection may be considered by topic or in a weighted, hierarchical system (e.g. Novotny et al. 2001). The need for this will be intuitive with a general knowledge of the opportunities under consideration.

Professional international location selection consultants are used by many businesses. According to World Bank's Investment Promotion Network (IPAnet 2001) the primary firms in North America and Europe include Deloitte & Touche-Fantas Consulting, Ernst & Young International Location Advisory Services and Prudential Business Location Consulting among several others. Spaulding & Slye/Colliers International is another international firm specialising in negotiating long term leases for government and private ventures. These firms can provide country options as well as site selection, based on the type of criteria outlined above and any other ones communicated by the client.

Finally, a government sponsored or supported production facility may be subject to other criteria for site selection. Governments may need to consider overall land use in their country and land suitability to particular activities. Production of sterile insects may take place in semi-industrialised areas, for example, rather than taking up prime agricultural land. Availability of government owned lands, a priority area for increased employment, proximity to an existing irradiation source, or the desire to incorporate this project into a scientific/technology park may impact site selection by government agencies. Donors may consider the FAO Guidelines for Land Use Planning (FAO 1989) and revisions of this approach (e.g. Warner 1994) along with overarching environmental plans for the country, rather than limiting decisions to an Environmental Impact Assessment of the single project.

Any of these additional concerns may be addressed if the initial criteria listed are met. Investors should be aware of any additional concerns of government sponsors and take into account the possible impacts of those additional criteria on profitability of the business.

3.3.3 Appraisal value

As a private business, a major part of the project's financial viability at any given point in time will depend on the actual Market Value of its real estate (including site improvements and buildings). Market Value is the value that appears on the company's balance sheet to raise investment and to justify loans. Therefore, the initial cost of purchasing or leasing the property and the cost of improving that property and constructing buildings can be either a major burden or benefit to the company.

In every economy, but especially in the changing conditions of transition economies, determining Present Market Value (PV) requires professional expertise. In business planning the Future Value (FV) also must be estimated at important dates in the conduct of the business. The FV is extremely difficult to estimate. Its predictability can be made more certain and risk can be lowered by good site location and cost controls. This has two financial benefits for the company:

- reducing uncertainty, which encourages investment;
- reducing risk, which decreases the rate of return investors demand for their loans or equity participation.

Box 3.3 Common methods for valuation and appraisal

To be clear about the difference between Market Value and other generally used concepts of value consider this quick review:

The typical appraisal addresses ***'Market Value'***: i.e. the probable selling price of a property (real or contemplated) on the open market given certain common sense conditions (good information, no stress, etc. or in other words an arms length open market transaction).

Other types of appraisal include -
Use value appraisal: given the expected net income from a particular use (say production of sterile insects), what is the appropriate factor (rate of return) that can be used to capitalize that income to produce Present Value (i.e. how much are investors paying for this kind of income, given this kind of risk?)

Replacement value: how much does it cost to build a facility of similar utility? The replacement does not have to be equal in every detail, just equally useful for the given uses that suit the subject property. We usually use this mainly for insurance or tax issues. It has little to do with the market.

Others not relevant to this case: historic, liquidation (salvage) etc.

Business valuation. This appraises an entire business rather than just the land and buildings. Usually income stream, potential or actual, is the most important factor. This kind of valuation is most appropriate when a business is established and operating, with clear trends in its cash flow. For setting up this enterprise, real property valuation is the beginning. For investors and for selling the enterprise, business valuation is more inclusive and includes the real property.

Finally, we have ***machinery and equipment valuation***. This appraisal form is used when determining the contribution to overall value made by the equipment and machinery (as distinct from real property in plant and land). Often this appraisal form determines the Market Value of the equipment and machinery for liquidation, bankruptcy, sale to another business, or insurance.

Source: Kaufman 2001.

For both PV and FV, the most important principle to keep in mind is that Market Value seldom equals the purchase price or the construction price. Market Value is that value for any given point in the past, present or future that equals the most probable price a well-informed willing buyer would pay and a willing seller would accept. That price may be more or less than the purchase and construction costs, but it is seldom exactly the same (Kaufman 2001).

The question is if this site and its neighbourhood have now, or will have in the future, factors that will decrease the value of the business compared to other sites. Factors to consider are environmental quality, trends in surrounding development or land use changes, probable government regulation or infrastructure activity and changing attitudes of nearby property owners and users.

'Partial rights', a situation in which one party holds the title to the property and another holds the right to lease and use the property, can also be appraised. If government land is provided for a project, the appraisal will consider the use value only for the company financial statement (Kaufman 2001). Box 3.3 explains common valuation/appraisal methods for determining the value of a property, assets or a business.

For the case of Slovakia presented in Annex 1, existing market conditions for both land and improvements can be determined by standard appraisal methodology used by appraisers experienced in the complex markets of former socialist countries (see more comments in Annex 1 on this case study).

Professionals arrive at an estimate of Market Value by three general methods: Comparable Sells; Replacement Cost; Income or Capitalization.[9] Appraised values are important for businesses, but they are not necessarily related to cash needs, cash flows or other financial calculations (Kaufman 2001). Discussion of the construction and operating costs of a production facility, and how this relates to the pricing of the product, appears in Section 6.

3.4 Protection of intellectual property

The WTO agreement on Trade-related Aspects of Intellectual Property Rights (TRIPS) summarizes the goal of intellectual property rights (IPR) in its Article 27 (WTO 1995b):

> "The protection and enforcement of intellectual property rights should contribute to the promotion of technological innovation and to the transfer and dissemination of technology, to the mutual advantage of producers and users of technological knowledge and in a manner conducive to social and economic welfare, and to a balance of rights and obligations."

In deed, achieving this balance between rights and obligations of IPR is a primary focus of many countries in their participation in both the WTO and the CBD.

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[9] COMPARABLE SALES. This method compares reliable data from actual free market sales. The properties compared must be similar to the subject property in potential or actual use, in size, location, age, and other variables. When data from several sales have been collected, the appraiser considers how these sales differ in character from the subject. For each difference he increases or decreases the sales price of the comparable sale. When this adjustment process is complete, the appraiser weighs each adjusted sale for reliability and similarity to the subject, and determines an estimated value for the subject.

REPLACEMENT COST. This approach, most applicable to proposed, new or almost new properties asks, "How much would it cost to build something similar to the subject property, similar in utility and quality?" From the market for construction materials and services, the appraiser determines the cost to build. He then subtracts from this cost three kinds of depreciation:

- physical depreciation: deterioration of both cosmetic and structural elements;
- functional depreciation: flaws in design or modernity that mean the subject property loses some market appeal and thus value (e.g. heating plant uses expensive fuel or electrical outlets are not numerous enough);
- economic or external depreciation: factors such as the character of the neighbourhood, transportation, pollution, etc. that might make the site undesirable for the proposed use.

INCOME or CAPITALIZATION APPROACH. The income approach applies almost exclusively to properties whose land and buildings can generate income from rents. (In business valuation, of course, it is applied to the income from the business activity.) The simple question here is this: given the real or potential rents a property could generate, how much would an experienced investor pay to capture those rents for a certain period of time. Determining this requires several sometimes difficult pieces of research:

- what might the actual net rents from the property be and what are the rents from similar properties?
- what relationship does the rental income from similar properties have to the price investors paid for them?
- how predictable and steady will the rents for the subject property be for the next five or ten years?

When probable rents and the rates of return investors require for buying properties that yield such rents can accurately be predicted, then the rents can be capitalized from the subject property. (That is, the annual net rent is divided by the rate of return investors require. An over simplified example: annual rent of $10,000 divided by 15 percent rate of return = $66,666 present value (PV) if this level of rent will continue for the foreseeable future.) *Based on Kaufman (2001).*

3.4.1 Methods for intellectual property protection

Various types of intellectual property protection exist that may apply to aspects of the SIT as it currently exists. The three primary categories for protection, and some examples of how that could relate to SIT, are:

- **Patents**
  - Innovative use of a known substance, compound, genetic sequence, etc.
  Examples for FAO/IAEA might be:
  The use of a known product as diet for mass rearing if the innovation is sufficiently novel.

  A patent for the genetic mutation that is the basis of some advantageous trait(s) e.g. mortality of females at a temperature still tolerated by males (although the IAEA is unlikely to patent a living organism).

  - New technology or methodology
  Examples for FAO/IAEA could be: new method for treatment or processing of blood for diet, new method for sterilization, etc

  Normally patents are a mechanism for capturing payment through royalties for the use of the intellectual property, however, royalty-free licensing is also an option. This would allow the IAEA to control the use of the knowledge without imposing any monetary demands.

- **Trade marks**
  - Identifiable symbol or name for a product or technology.
  Examples for FAO/IAEA could be:
  Allowing the use of the IAEA symbol in material referring to the genetic strain coming from that lab, or developing a name that is recognized as reputable for some process that will be used by others and thereby maintaining some contractual control over their process.

- **Copyrights**
  - Written materials or software
  Examples for the IAEA may include training videos, manuals such as quality control or standard operational practice manuals, software models. The spreadsheet designs developed for SIT programmes using funds from the Joint Division may also warrant copyright.

Some works could be subject to patent, trademark and copyright protection simultaneously. A product is normally granted only one type of protection, however. Patents are normally associated with things and processes; copyright is used for expressive works (books, music, but also software and videos). Trademarks apply to the name, logo, colour or other methods for identifying the source of goods (AllBusiness 2001c).

Another UN Agency, the World Intellectual Property Organization (WIPO), based in Geneva, works to harmonize protection of IPR through treaties and international discussions. The WIPO's Patent Cooperation Treaty accepts international applications for patents in place of the usual system of applying for a patent in every country where an invention will be used. This approach is gaining more acceptance, as shown by the numbers of applications under this Treaty, which rose from 7000 in 1985 to 74 000 in 1999 (UNDP 2001). Applications are overwhelmingly from the developed countries that have historically dominated patents: for example the USA (41.8 percent), the EU (39.25 percent) and Japan (8.9 percent) of the 54 422 filed in 1997 (Juma 1999).

While many multilateral intellectual property agreements have existed over the years, efforts to harmonize the national approaches to IPR culminated in the TRIPS Agreement of the WTO, which came into effect in 1995. The key elements of IPR protection were the same in the US, Europe and Japan – the largest sources of patented inventions. Some of the points that differed, however, are critical to the subject of SIT: the scope of technology that is patentable, treatment of IPR for plants and animals, and the influence of moral and ethical values on granting IPR (Juma 1999).

Under TRIPS, exclusion of certain areas of technology from patentability is not allowed (Article 27). The practice of excluding areas of technology considered to be important for public welfare (e.g. pharmaceuticals) historically was used by some developing countries, but gave no advantage to the producers and thus did not support innovation. Drug development in particular is an expensive endeavour (easily as much as US$500 million per drug) due to the direct costs, the low approval rate of those developed and the subsequent competition from generic or competing drugs. In these high cost situations, IPR provides the control needed to "provide a predictable environment for product development" (Juma 1999).

Alternative methods of fulfilling the public interests are under debate and require a great deal of additional consideration and dissemination. In the past, some intellectual property has been used extensively by lower income countries without entering into licensing agreements or paying royalties, but in these cases the innovation was used domestically and did not result in exports. This does not support the producer of the technology or encourage full access to the benefits by those countries. The moratorium on violation complaints under TRIPS against developing countries has ended, although some countries will voluntarily extend it (Juma 1999).

The TRIPS Agreement allows for the development of other policy approaches such as use of generic drugs, government support for research of national priorities, compulsory licensing of patented technology used in their country, or the development of an international Working Group aimed at technology transfer, as proposed under the WTO by India (Juma 1999). Because so much of the development of SIT has taken place under the auspices of humanitarian institutions or public service institutions, primarily the IAEA and national governments, these debates regarding the appropriate protection of future intellectual property are relevant to sterile insect production businesses as well.

3.4.2 United Nations agencies and intellectual property

The IAEA ensures the ownership of any material developed by consultants to the programme through a contractual clause. However, no innovation can be protected if it is already in the public domain in any way. Therefore, anything that appears in publications, training materials or public presentations does not qualify for intellectual property protection after the fact. Even if the innovation has been discussed in documents, correspondence including email, or closed meetings, the innovation is considered public unless these occurred under strict confidentiality. Also, the innovation must be sufficiently significant to warrant a patent in the eyes of the granting country's Patent Office. Minor innovations that would have occurred to anyone employing the publicly known process of SIT, for example, would not be eligible for intellectual property protection.

Intellectual Property Rights have not been pursued by FAO as a general policy. In accordance with the UN Charter, intellectual innovations or discoveries from work by the FAO has been considered "property of humanity" and available for all to employ. The FAO Legal Office is only aware of a single technology patent, one trademark and one technology that have been licensed by FAO. A more recent policy of FAO is to investigate the value of IPR for innovations developed by or through FAO projects.

Other UN Agencies have also expressed increasing interest in protecting UN-derived intellectual property for the public good it was intended to serve. This interest has been shown, for example, by discussions on the topic at the annual meeting of Legal Counsels of the UN Agencies. Although nothing yet has been resolved in this forum, it is an interesting avenue through which the IAEA may pursue the matter. In addition to any direct benefits from protection of intellectual property, the existence of patents on technology used in sterile insect production is reassuring to potential investors in the cooperating production facilities.

Future possibilities for new intellectual property include innovations by the IAEA or by the private investors. They also include innovations arising from joint collaboration. It is likely that innovations by private investors will simply be patented by those individuals or companies. This will result in the required payment of some royalties from other SIT production facilities that wish to use the innovation in the future. The only way to prevent a private group from usurping the IPR of something developed with IAEA collaboration and technologies is to address this issue in a contract prior to the collaboration. Such a contract might require that the private firm's innovations be shared with all the users of SIT. It is unlikely that private investors would agree to those terms for anything of real significance, but it may clarify the attitudes of both parties towards minor innovations and pave the way for the free dispersal of these minor innovations.

The IAEA is discussing intellectual property protection within its policy-making organ. Issues to consider include:

(1) Protection of IAEA intellectual property to prevent some other party from patenting it.

(2) Protection of IAEA intellectual property to ensure the proper use, application and transfer of it (and thus maintain its quality standard).

(3) Protection of IAEA intellectual property as a means for supporting future work by somehow capturing income from private interests that gain a profit by using IAEA work.

Historically IAEA work is in the public domain and could not be patented. As private companies become involved in the use of SIT technology, humanitarian or public service considerations may encourage the approach noted in point 3 above.

The IAEA may wish to obtain guidance from the World Health Organization (WHO) or other UN bodies that have more experience with IPR (see Box 3.4). The Japan-headquartered International Service for the Application of Agri-biotech Applications (ISAAA) might also be consulted for mechanisms to protect IPR while upholding the mission of the IAEA, although ISAAA works only with patents of innovations in crops. The ISAAA supports the Consultative Group on International Agricultural Research (CGIAR), for example, in their attempts to develop IPR regulations (Thwaites and Seal 2001).

Box 3.4 How WHO addresses the protection of intellectual property rights

The World Health Organization (WHO) has a long history of working with commercial interests, primarily pharmaceutical. WHO carries out Research and Development, which sometimes leads to patents. Often WHO uses licensing to get the product into distribution. The R&D falls into three categories:

(1) Innovations worth protection of Intellectual Property Rights (IPR) usually arise from collaborative projects in which both WHO and private interests participate in the research. IPR is usually transferred for commercial development, and the liability is transferred as well. WHO transfers IPR to the group that will commercialize the discovery, but they contract it so that benefits will go to the public at large, with the public sector of developing countries getting preferred pricing. Whether or not the innovation is eligible for patenting, WHO seeks to maintain the details of the innovation as confidential (a common practice in industry). Therefore, if the innovation is not commercialized by the first company, rights revert back to WHO without any loss of value from publication of the innovation and a second company can be sought to carry out the commercialization.

(2) IPR when WHO only provides the funds but does not participate in the research. In this case, WHO does not maintain IPR, but they do negotiate as above to try to protect the confidentiality of the process for future exploitation and to get preferential pricing for developing countries.

(3) IPR for something that is WHO's own idea without collaboration. This may also be passed on to commercial interests in order to effectively commercialize the innovation. Their primary objective is to get innovations out for the benefit of people. If they are able to further negotiate royalties that is considered an added benefit.

WHO has examples of contractual language for all of these categories. The legal office of WHO advises caution in use of patents because it has to be something worth the expense and time to warrant patenting. One has to patent the innovation in the countries where the technology will be used or applied, as well as where it is developed. There can be many challenges to this method for IPR protection. However, if it is worth patenting, then the earlier one can get agreement with a commercial interest the better. That way the costs are shared with this business and they are involved in the time consuming process.

3.4.3 Future issues in intellectual property

One of the greatest controversies surrounding IPR regards patenting of living organisms. The TRIPS Agreement states (Article 27) that essentially biological processes cannot be patented. Some interpret this to mean that classic breeding methods are excluded, but that genetic engineering methods may be patented. While naturally occurring living organisms may not be patented, GM insects may be eligible for patenting. There is a wide divide among countries on this issue, with the US allowing a much broader range of patents while the EU, the African Group and others have expressed concern over patenting of any life form (Juma 1999).

The issues are very complicated. In general, TRIPS language supports the extension of patents to plants and animals (microorganisms are already included in the current system), but developing countries in particular have raised objections. Most objections are based on the historic commercialization of genetic resources without compensation back to the country of origin or the source of indigenous knowledge that led to the discovery. Historically, WIPO has also focused on industrial property and has been criticized for lack of understanding of farmer rights and other issues that arose in the TRIPS under the WTO.

As with discussions on risk assessment, this has focused heavily on plant material. Individual countries have set up contracts with companies in order to receive some compensation for the "bio-prospecting" that goes on within their borders. The relationship between these governments and benefits to indigenous people is not always clear (Juma 1999). (A point of contention has been the use of "terminator" genes to prevent farmers from collecting seed of the improved variety. These discussions should not be confused with the use of sterilized organisms for pest control.)

The most extreme outcome of these debates could be that the IAEA and their collaborators will need prior informed consent and some arrangements with the source country of their genetic material (i.e. of the insects captured for an initial colony) regarding benefits derived from these. Since the benefits often are going back to those countries themselves, or their neighbours, this extreme scenario seems unlikely to pose barriers to future developments in SIT.

In conclusion, in the private sector technology is generally developed in response to market demands, not for the poor. Developing countries have less ability to address the technical and economic risks that arise from market failure. Government incentives generally are not available. For this reason, national policies alone cannot compensate for global market failures (UNDP 2001). Any technology or product developed by the IAEA has a unique obligation to serve humanity. The fulfilment of that mission requires commercialization of the SIT in order to meet its full potential as an environmentally preferred approach to pest control.

The SIT technology was initiated and further developed to a large extent in response to market demands from the livestock and fruit growing industries. The IAEA has since provided invaluable support to advance the technology and develop strains that make SIT more cost effective. There are many new uses for SIT that will be primarily humanitarian, due to the target pest or the country in which SIT will be applied. Commercialization of the technology requires use of a market scenario, which can only be achieved with recognition and protection of IPR. With this protection, the IAEA and its sister agencies can interject some requirements for the commercialization of UN "products" that will support the proper use and fair dissemination of its inventions. Without IPR protection, there is no control over how innovations will be used by the commercial sector.

3.4.4 Special issues for e-commerce

A production facility that is going to use Internet for conducting business must also review the Internet laws related to their facility location, and also possibly to their market countries. This is particularly the case if a publicly accessible web site will be used for sale of sterile insects. Some of the questions to consider are:

- who are the regulators for that country/region;
- is the business/web site aimed at a market that has different regulators/rules;
- what is the status of on line contracts, digital signatures, etc.;
- are there any contracting procedures peculiar to Internet for these markets;
- under what laws will electronic contracts be upheld;
- will copyright of materials posted on Internet be protected;
- are there consumer laws that impact business over Internet differently than other business;
- is there Value Added Tax or other taxation on Internet commerce;

- what laws impact on pricing of goods via e-commerce;
- is the company providing secure privacy on line;
- and what needs to be done for domain registration.

E-commerce law is very recent. For example, Harvard Law School offered their first course in Internet Law in 2001. The European Directive on e-commerce (00/31/EC), the Electronic Commerce Directive, was adopted on 8 June 2000. All EU member country will have national laws and/or regulations to transpose the Directive requirements into national instruments. Because these issues are not yet harmonized globally, this research must be done on a case by case basis.

3.5 Insurance requirements and liability

Insurance is the most common approach for private businesses to address risks. By obtaining insurance for each of the anticipated risks, the private business essentially pays to lower the risk to itself by spreading the risk to a group. The group of insured businesses pays for what actually occurs (claims made on the insurance) through regular premiums.

This report uses a value of approximately 1 percent of the capital expenditure for the cost of insurance for sterile insect production facilities and shipment of their products (see Section 7 synthesis on financials).

3.5.1 Private insurance

As with any business, insurance coverage should be considered for:

- fire, flood, earthquake or other destructive events (e.g. some policies cover sewage and other plumbing events, electrical systems, etc.);
- theft or loss;
- computer systems protection, related business losses;
- liability for law suits arising from business activities or in case of an accident at the location (determine the liability of the company related to the post-sale shipping, storing, release and effectiveness);
- loss of business due to other damages;
- terrorism or acts or war (not covered by most insurance policies).

Private firms may wish to have “key man” or “overhead” insurance in the event that an individual who is key to the operation of the facility cannot work for some period. Life insurance on the key owners/operators with the business as the beneficiary is also helpful in a time of crisis.

Health, life and disability insurance may be offered to the employees of the plant, in compliance with any national laws and general company policy regarding benefits. In general, insurers are more interested in larger businesses than small ones. Although the increase in revenues and work force imply a greater risk, they also provide a better basis on which insurers can calculate claims, and therefore premiums. A larger group also spreads risk among more people. While this growth in the business may lower unit charges for health care, other types of coverage such as worker’s compensation and liability will necessarily go up (Martin 2001).

3.5.2 Liability

There are several types of liability, the most common of which include personal injury, property damage and damage from products (Harroch 2001).

It is traditional for law firms, for example, to carry "errors and omissions" insurance in case their advice leads to a loss for their client. A sterile insect production facility should be excluded from this type of liability either by avoiding the offer of results (versus a product – see Section 3.7.1) or through contractual means.

Contractual language should also cover losses due to failure of equipment or delays during transport. Yet even non-commercial groups often insure shipments of insects that are being sent over long distances in order to recover some costs of additional production and shipment in case the original shipment fails to reach a project in time (Lopez, 2001). The unlikely event of an accidental release of mass reared insects that were not properly sterilized, or of improper identification of a sterile insect as if it were not sterilized, should be discussed with plant health officials in the country of release to clarify any issues of liability in advance (Enkerlin and Quinlan 2004).

Because of the importance of contractual coverage, the investors/managers should establish under which jurisdiction the contracts will be upheld – the country of production or the country where the purchase and release will be done. This should be handled under the advice of an attorney on a case by case basis.

3.5.3 Enforcement of contractual agreements and arbitration

While contractual language is recommended to achieve some protection against liability, it is essential that any contract establish the laws under which it will be enforced and whether both parties are agreeing in advance to use of arbitration when possible.

Should a breach of contract arise, there are a number of avenues employed to resolve disputes that offer an alternative to the courts. Arbitration is most commonly used and the advantages for doing this are clear. An enforceable decision from a commercial dispute can only be achieved through the courts or through arbitration. Arbitral awards are not subject to appeal, which often makes them more final than court rulings.

Arbitration has great international recognition and the 1958 UN convention on the recognition and enforcement of arbitral awards (commonly called the New York convention) has been signed by over 120 countries. The convention decrees that arbitral awards can not only be made by the arbitrators appointed in each case, but also by permanent bodies to which parties have been submitted (such as the International Chamber of Commerce – Court of Arbitration).

Each nation that has signed the NY Convention recognizes an agreement in writing under which parties submit to arbitration differences, which may arise in respect of a defined legal relationship whether contractual or not (if the matter is in fact capable of settlement through arbitration proceedings). "Agreement in writing" includes arbitral clauses in contracts signed by involved parties, or those agreed in some communications. If a matter arises in a court of law, which can be referred to arbitration, then it shall be unless the contract/agreement is declared null and void. This can occur under an array of circumstances such as if the defendant party claims to have been under some kind of incapacity at the time, or the agreement was not lawful at the time of signing.

The nations that have signed the NY Convention recognize arbitral awards as binding and enforceable, in accordance with the rules of the procedure of the territory where the award is relied upon (e.g. the fees for arbitrations under the convention shall concur with those of domestic arbitrations in that nation). To obtain the recognition and enforcement above, the party must supply the authenticated award and the original contract/agreement. Furthermore, these must be submitted in an official language of the member nation. The party against which the arbitration award is invoked can dispute it to the authorities under some conditions (e.g. the agreement/contract was invalid – here proof is required). Enforcement can also be refused if the authority finds that the matter cannot be settled by arbitration or the recognition of the award would contradict domestic policy.

Contracting states may well have entered into bi/multilateral agreements concerning the enforcement of arbitral awards and any legislation of this type must be concurred to as well as those adhered to in the NY agreement. Proceedings can take place in any country and participants can be of any nationality. The process is a lot faster and cheaper than litigation in courts of law. Finally, arbitration is confidential, only the parties involved receive copies of the awards.

The International Centre for Settlement of International Disputes (ICSID) of the World Bank Group provides facilities for conciliation and arbitration disputes between member countries and investors also from member countries. The ICSID was established under the Convention on the Settlement of Investment Disputes between States and Nationals of Other States (1966) and has an administrative council and a secretariat. Besides arbitration facilities, ICSID also administers certain types of arbitral/conciliatory proceedings between member states and non-member states under the Additional Facility Rules. Furthermore, ICSID can provide facility conciliation for cases, which do not involve an investment but that have "features that distinguish it from an ordinary commercial transaction." The ICSID can also provide fact finding proceedings in certain cases. Finally, ICSID acts as an appointed authority of arbitrators for non-institutional (ad hoc) arbitration proceedings. The ICSID's members are also members of the World Bank.

3.5.4 Political risk insurance schemes

Because of the location of many SIT programmes, investors will be concerned about any reasons for non-payment from the potential customers for the product. The possibility of war or other civil unrest, drought or other natural disasters is equally a threat to the continuing operation of the production facility if the disaster occurs at its own site as it is at the site of the SIT programme that is an important customer. Business managers have found that political risk insurance is not as easy to obtain and collect from as it would appear (K. Waters, pers comm 2001). Projects with local government involvement may be easier to insure.

The Multilateral Investment Guarantee Agency (MIGA) is a member of the World Bank Group specifically created to promote FDI into emerging economies to reduce poverty. MIGA offers political risk insurance to investors and lenders and provides assistance to developing countries in attracting private investment. MIGA often works with other partners to insure new, cross-border investments in developing countries among MIGA members (see Table 3.2 at the end of Section 3).

A preliminary application must come before investments are made or committed to the project. Investors may choose a combination of coverage (i.e. breach of contract, war, transfer restriction or expropriation) for up to 90 percent of equity and 95 percent of debt for up to 15 years. Although guarantees may go up to US$200 million, smaller projects are also considered by this insurer. For example, a synthetic yarn company in the Slovak Republic received a US$713 000 guarantee on an Italian investment for expansion and modernisation of the business. This project came under a joint programme by MIGA and the Italian development finance agency, SIMEST, focusing on SMEs.

Regional and individual country programmes in political risk also exist. For example, the Islamic Development Bank (IDB) has an investment insurance system covering up to 90 percent of direct investment in either private or public projects, as well as loan guarantees similar to the programme under MIGA. The IDB only covers investment between its 53 member countries (see Table 3.2) and in accordance with Islamic investment principles.

The USA has the Overseas Private Investment Corporation (OPIC) to provide insurance, financing, and advocacy for US investors participating in all sizes of investments in 140 developing countries (see Table 3.2). OPIC support can go to new projects, privatizations, expansions, or acquisitions of existing businesses that cannot secure financing through commercial sources. The investor may need host government approval before receiving OPIC support. The OPIC has recently announced a new private investment support facility for projects in Sub-Sahara Africa, offering loans, guarantees and risk insurance for US investments (OPIC 2001).

The Export-Import Bank of the United States, EXIM Bank, can use distributors' guarantees to show the market demand. For example, with the production of a cinema film the distributors can guarantee a certain level of income for the production even though the film is not yet released. In essence, they are saying they will pay that amount regardless of what happens in reality[10]. This shifts the liability. This programme is very limited in scope, however, as only US services and goods manufactured in the US can be covered by the EXIM Bank.

3.5.5 Costs of risk

When considering the costs of risk, privately owned facilities are at a disadvantage to government facilities because of the limited ability to absorb risk. For this reason, it is essential for private facility investors to understand the potential risks and account for them in financial projections. Some government facilities quantify risk and include this in costing and plans, for example the risk of earthquakes (see Section 5.3.4.) While the costs of obtaining all of the insurance suggested in Section 3.5 may seem prohibitive, making various types of insurance a regular line item in the budget allows a facility to properly include this protection in the pricing for the product. There are other risks that cannot be insured in the current insurance industry. These are discussed under Section 6.3 on pricing of the product.

A production facility could be contracted to serve as the backup for other facilities producing the same species. This will be most important for species that are harder to colonise and mass rear, such as the tsetse fly. For a more commonly reared species such as Medfly, there is a built in "insurance" of having competing facilities so that if one falters in production during a control campaign, another facility can provide the supply for some short period. Futhermore,

[10] This approach is worth considering in line with financing on the outtake, see Section 3.2.2. This is only likely if the buyer is a government or a donor program that can afford to absorb some of the risk.

Medfly production can recover and build back up to higher numbers in a relatively short time frame.

Tsetse fly, however, takes some time to reproduce (see Section 4.5). It is not uncommon for an entire colony to perish or numbers to drop precipitously. For this type of species, a backup colony will be key to successful control campaigns. This may be achieved through multiple units at one location or multiple locations belonging to or contracted by one company. Another approach is for the interested buyers (or funding sources) to finance a backup colony, either directly as insurance or through higher prices per unit on the primary supply.

This concept of a back -up facility has been considered by the NWS eradication programme. A backup facility would be needed in case of a large outbreak or in case of the mortality of the breeding colony. The loss of the colony could result in no release of sterile flies for 6 to 14 months, which is the time it would take to collect a new strain in the wild and adapt it to the laboratory conditions then reach a sufficient production level (Sheesley et al. 2001 Appendix 6b). Presently, there is only one NWS production facility located in Tuxtla Gutierrez, Mexico. A new facility is to be built in Panama, where it will continue in operation for the foreseeable future in order to produce flies for a permanent barrier zone at the Darien Strait. If the original facility is maintained, it will serve as a backup for the new one.

Risk mitigation of this nature cannot be bought through the insurance sector and will be difficult to price (see Section 6 regarding current approaches to pricing). Failure to provide biological insurance on this type of species could cause enormous losses if a control campaign were impacted mid-stream.

3.6 Market considerations about technologies

Today's markets demand environmentally suitable technologies that maintain high efficacy. The sterilization[11] process in production of sterile insects may be misunderstood by those not familiar with nuclear technology. Some public education may be required to eliminate unfounded concerns. The use of genetic engineering may also cause concern by some parties. The current practices for development of insect strains for mass rearing through classic genetics should be distinguished from transgenic modification technology. Aerial release of insects may also cause alarm among a public that is not informed about the SIT programme. The concerns regarding release are not the responsibility of a production facility. Yet a facility that is willing to work with the buyer of the sterile insects in advance to respond to these concerns will probably prove more successful.

3.6.1 The sterilization process

Sterile insect production facilities do not have nuclear reactors but rather a source of radiation for use in sterilization. The irradiation source is an expensive component of the capital costs for a production facility that incorporates sterilization at the same location.

Every atom consists of a defined number of electrons surrounding a nucleus of protons and neutrons. Nuclear radiation is produced when the contents of a nucleus are disrupted, therefore changing its nuclear binding energy. Four main types of radiation exist: alpha (α),

[11] The IAEA definition for sterilization is the "elimination of the ability to reproduce" (see IDIDAS glossary, Web site resources). It may also mean the process of killing all living microorganisms from a sample, such as the sterilization of medical instruments, but this latter definition is not the one intended in this report.

beta (β), gamma (γ) and neutrons. Standard international units of radiation measurement are the Gray (or rads) and Sievert. Other measurements such as the Curie and Rem are also used but refer to the dosage of radiation received by exposed individuals rather than an absolute measurement of radiation.

Things can be naturally radioactive if they have an unstable nucleus. To make something radioactive, therefore, the nucleus needs to be destabilized. This can be done via neutron bombardment or very high-energy gamma radiation. The radioactive source will generally be produced in a research reactor and be processed to select a particular type of radioactive atom, or radioisotope. This may consist of a large frequently regenerable system, such as a cobalt-60 (^{60}Co) source, an intense gamma ray source, or a "point" source of radiation sealed in a stainless steel container in air, such as caesium-137 (^{137}Cs) with the source normally stored behind significant lead and concrete shielding. Items to be irradiated may be lowered into the water surrounding the source, or moved past the radioactive source. An object that has been irradiated does not become radioactive because irradiation only affects the electrons of an atom and not its nucleus. Insects or other arthropods that are sterilized by radiation for SIT programmes are not radioactive. Workers in an SIT production facility are not exposed to more radiation than considered safe by calculating cumulative exposure over the period of a worker's career.

The necessary competencies for the person in charge of the sterilization process appears in Section 3.2.3. The IAEA provides guidance and training in qualification of the dose from each source. Failsafe procedures to ensure that the insects were in fact irradiated before leaving the plant are also in place.

Although some precautions should be taken in the course of the sterilization process, in general proper education of the community surrounding the facility, the investors, or others concerned should alleviate any worries about the use of this technology.

3.6.2 Radiation versus other methods of sterilization

Mutagenic chemicals were evaluated in the early days as a method for sterilization in place of irradiation. These chemicals could be added to the rearing diet or applied directly to the developing eggs or pupae. It was found that the chemicals remained in the system of the insects and could spread, causing environmental consequences beyond the rearing phase. There was also concern about disposal of the hazardous diet remains. Although research in this area continues with a search for less toxic chemical sterilizers, mutagenic chemicals are not used in any commercial production facility. With the current state of knowledge, irradiation is much safer than chemical sterilants for the facility workers and the environment.

Very recently, there is some doubt about the future availability of small scale reactors due to concerns of the manufacturers about the market and the additional security required in modern times. X ray equipment has already been tested for use with some of the SIT species and further testing is underway at the IAEA for this new approach (Hendrichs 2007).

3.6.3 Other uses of nuclear technology for pest control

In addition to its use for sterilization of insects for SIT, irradiation can also be used for other approaches to pest control (FAO/IAEA 2001b). Uses of nuclear techniques for the colonization and production of biological control agents of agricultural insect pests are under study through a Co-ordinated Research Project of the FAO/IAEA (Project D.4.02, Task 4).

Normally risk analysis is conducted to predict the specificity and possible impact to non-target organisms of a potential biocontrol species. If the analysis is favourable, the biocontrol agent is approved for field release. By releasing sterile biocontrol agents in initial studies, however, their interactions with the target and non-target species and the ecosystem in general may be monitored without any consequences past the single generation. This tool for determining the appropriateness of a species for mass release into the environment holds great promise for national regulators (FAO/IAEA 2001b). It is an exciting use of nuclear technology from the point of view of protection of biological diversity.

3.7 Other commercial considerations for marketing sterile insects

3.7.1 Selling a product or the results

Sterile insect production facilities have traded in terms of million sterile males shipped. In-transit losses are expected within a predetermined range. Another approach to sales is to provide results. Although this is not the usual approach used for pricing, it is implicitly underlying all sales (see Section 6 for discussion on pricing). Results will be in terms of reduction of damage to crops, costs competitive with the pesticide option and, for more sophisticated buyers, the opening of new markets due to pest free area status or to residue-free products. It has been harder to estimate the reduction of environmental impacts, although interest in this is growing (see Sections 2.2 and 5.5).

Quality control in terms of the sterilized insects' attractiveness as a mate has always been a major focus of research in this business. As with pesticides, however, achieving results is not entirely within the control of the provider of the pest control product. Private sterile insect production facilities may choose to offer a wider range of service to support the efficacy of their product than is normally considered by government suppliers. These services may include support for design and evaluation of feasibility of an SIT project; field monitoring to determine the appropriate release numbers and to determine the status of the population, training of staff and other implementation activities (A. Larcher-Carvalho, pers comm 2001).

Whether these services are provided by the production facility or not, the facility managers must always make clear what the customer is purchasing so that the implicit expectation of results may be addressed.

3.7.2 Public relations and community support

Public relations (PR) programmes are required to gain the support of the general public and of other stakeholders such as governments, financial institutions, producers and exporters (FAO/IAEA 2000a). Public awareness and relations campaigns are essential for SIT programmes because they are new and fundamentally different from previous pest management systems: they are large, centrally managed and use a technology largely unknown to the public. In addition, they are visible to the general public (FAO/IAEA 2000a) and may affect whole communities.

Effective communication methods need to be creative (Klassen 2005) and are best developed by communication experts (Dyck et al. 2005a). Various materials may be used including the production of printed media such as brochures, newsletters and posters; development of a logo or mascot figure (e.g. Figure 3.2). Several projects have developed websites. These may refer to other SIT information from the IAEA website, including its newsletters and publications.

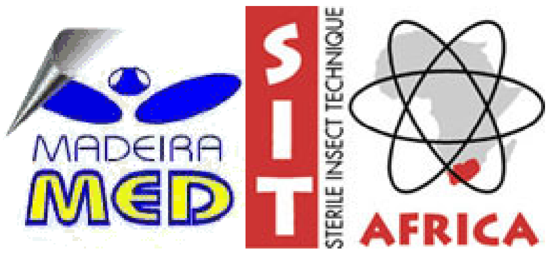

FIG. 3.2. The logo of two SIT programmes
(Sources: http://www.sra.pt/~madeiramed/, and http://www.arc.agric.za/institutes/infruit/main/divisions/sit/sit_africa.htm).

Information on technology, programme goals and achievements can be provided in an understandable and transparent manner. It is necessary to address, in a clear and practical way, potential public fears and highlight the benefits of SIT to the community and the country (Linquist 2000). The perception of SIT as environmentally preferable to the alternatives is important to highlight. The message must be designed to target publics with different levels of knowledge and must be sensitive to different concerns. This is particularly true for the public in urban areas, which tend to be more sophisticated and complex, (Dyck et al. 2005a). Convincing evidence, supported by scientific data, about the benefits of the project is necessary. Otherwise, activities may appear intrusive, annoying (Lorraine and Chambers 1989, Mangan 2005) or even dangerous for human health.

The media can be effective partners by informing the public about a programme, especially if this is done in a non-technical way. Newspaper, radio and television appearances directed at the general public living in the treatment area are options. There also must be some form of community engagement, however, following effective communications models. PR models (Grunig and Grunig 1992) can include one-way communication generated by the organization, as in the case of brochures and press releases. They can also include two-way communication: asymmetrical models (in which an organization gets input from the public but uses it to convince those same publics) and symmetrical models. In the latter models, organizations use research and communication methods to better understand their publics and, thereby, facilitate understanding and communication rather than to simply persuade the target community to obtain agreement (Grunig and Grunig 1992).

Inadequate public support can cause programme failure: serious problems have occurred in the past with area-wide pesticide programmes. For instance, during the Medfly eradication programmes in Florida in 1997–98, strong opposition by the public and activist groups distracted important resources into an “emergency” public information campaign (Dufresne and Telg 2000). Indeed, an analysis of the Florida agricultural communicators' PR efforts showed that much of the early communication efforts by government agencies responsible for eradication were mostly in the one-way model: issuing press releases and giving press briefings, which were insufficient for the target audience. While the methods used were effective in getting across information, such as the possible impact of infestations and the need for eradication, the public wanted the opportunity to give its input. Subsequently two-way, symmetrical modes of communication also used in the Florida campaign, including public meetings and face-to-face interaction, proved to be the most effective in allaying public fears. This two-way model should become the communicator’s "first line of defence" (Dufresne and Telg 2000).

To avoid these risks and allow for local knowledge and ideas to influence the programme, a proactive communication plan addressing the information needs of the general public, affected communities, environmentalists and other community organizations, should be developed at the start of an SIT programme to guarantee its success. For PR to be effective, SIT programmes must be staffed with full time PR experts or include a similar arrangement through outsourcing. A PR plan must be tailored to each programme’s characteristics and socio-economic conditions.

A key element of the communication plan is to secure support from those groups affected by the programme and that may be called to participate in its operations. Travellers at checkpoints and other quarantine barriers may be asked to declare or bag fruit so adequate information must be provided to ensure compliance. Producers may be asked to grant access to their property or implement cultural control measures in their farms. A PR programme targeted at producers must be initiated to overcome producer reluctance to adopt SIT and gauge their support for the project operations. Producers, too, are not used to this type of control system. Commodity group organizations could lead this effort. Finally, support must be sought from all those who may contribute financially to the programme: these may be farmers and their associations through levies or taxes, financial institutions and government authorities. Consultation with other stakeholders may also be required: support from the local community must be assessed and developed prior to the construction of a production facility to avoid later conflicts or misunderstandings.

The most challenging aspect of the PR work is to obtain political support (Tween 1993, Pereira 2001) from governments and other important organizations (e.g. international organizations) which may bring credibility to a programme. This may be in the form of legislation and regulations needed to operate the programme, to provide financial backing and to legitimize and empower it. Governments, financial backers and international supporters require regular reporting on financial status, benefit distribution and public support (Dyck et al. 2005a). Support from these groups may be sought in the form of partnerships with key governmental, international and industry institutions. Early meetings with industry groups supported by the publication of feasibility studies, articles in industry magazines or farm radio programmes are some of the approaches followed to gain support.

Table 3.2. Country membership or qualification for funding and investment guarantees in example organizations (October 2005)

Country	UN Agencies			World Bank Group			Regional	Bilateral		
	UN[a]	**IAEA**[b]	**UNDP**[c]	**IBRD**[d]	**MIGA**[e]	**IFC**[f]	**IDB**[g]	**OPIC**[h]	**USAID**[i]	**DfID**[j]
Afghanistan	X	X	X	X	X	X	X	X	X	X
Albania	X	X	X	X	X	X	X	X	X	X
Algeria	X	X	X	X	X	X	X	X		
Andorra	X									
Angola	X	X	X	X	X	X		X	X	X
Anguilla								X		X
Antigua and Barbuda	X			X	X	X		X		X
Argentina	X	X	X	X	X	X		X		
Armenia	X	X	X	X	X	X		X	X	X
Aruba								X		
Australia	X	X		X	X	X				
Austria	X	X		X	X	X				
Azerbaijan	X	X	X	X	X	X	X	X	X	X
Bahamas	X			X	X	X		X		
Bahrain (Kingdom of Bahrain)	X		X	X	X	X	X	X		
Bangladesh	X	X	X	X	X	X	X	X	X	X
Barbados	X		X	X	X	X		X		X
Belarus	X	X	X	X	X	X			X	
Belgium	X	X		X	X	X				
Belize	X		X	X	X	X		X		X
Benin	X	X	X	X	X	X	X	X	X	X
Bermuda										
Bhutan	X		X	X		X				
Bolivia	X	X	X	X	X	X		X	X	X
Bosnia and Herzegovina	X	X	X	X	X	X		X	X	X
Botswana	X	X	X	X	X	X		X		X
Brazil	X	X	X	X	X	X		X	X	X
British Virgin Islands										
Brunei Darussalam	X			X			X			
Bulgaria	X	X	X	X	X	X		X	X	X
Burkina Faso	X	X	X	X	X	X	X	X		
Burundi	X		X	X	X	X			X	X
Cambodia	X		X	X	X	X		X	X	X
Cameroon	X	X	X	X	X	X	X	X		X
Canada	X	X		X	X	X				
Cape Verde	X		X	X	X	X		X		

Country	UN Agencies			World Bank Group			Regional	Bilateral		
	UN[a]	IAEA[b]	UNDP[c]	IBRD[d]	MIGA[e]	IFC[f]	IDB[g]	OPIC[h]	USAID[i]	DfID[j]
Cayman Islands										
Central African Republic	X	X	X	X	X	X		X		
Chad	X	c	X	X	X	X	X	X		
Chile	X	X	X	X	X	X		X		
China (People's Republic of China)	X	X	X	X	X	X				X
Colombia	X	X	X	X	X	X		X	X	X
Comoros	X		X	X		X	X			
Congo, Democratic Republic of	X	X	X	X	X	X		X	X	X
Congo, Republic of	X		X	X	X	X		X		
Cook Islands								X		
Costa Rica	X	X	X	X	X	X		X		X
Côte d'Ivoire	X	X	X	X	X	X	X			
Croatia	X	X	X	X	X	X		X	X	X
Cuba	X	X	X						X	X
Cyprus	X	X	X	X	X	X		X	X	
Czech Republic	X	X		X	X	X		X		
Denmark	X	X	X	X	X	X				
Djibouti	X		X	X		X	X	X		
Dominica	X			X	X	X		X		
Dominican Republic	X	X	X	X	X	X		X	X	
East Timor (Democratic Republic of Timor-Leste)	X		X	X	X	X			X	X
Ecuador	X	X	X	X	X	X		X	X	X
Egypt/Arab Republic of	X	X	X	X	X	X	X	X	X	X
El Salvador	X	X	X	X	X	X		X	X	X
Equatorial Guinea	X			X	X	X		X		
Eritrea	X	X	X	X	X	X		X	X	X
Estonia	X	X		X	X	X		X		
Ethiopia	X	X	X	X	X	X		X	X	X
Falkland Islands										
Fiji	X		X	X	X	X		X		
Finland	X	X		X	X	X				
France	X	X		X	X	X				
French Guiana								X		
Gabon	X	X	X	X	X	X	X	X		
Gambia	X		X	X	X	X	X	X		X
Georgia, The Republic of	X	X	X	X	X	X		X	X	X
Germany	X	X		X	X	X				

Country	UN Agencies			World Bank Group			Regional	Bilateral		
	UN[a]	IAEA[b]	UNDP[c]	IBRD[d]	MIGA[e]	IFC[f]	IDB[g]	OPIC[h]	USAID[i]	DfID[j]
Ghana	X	X	X	X	X	X		X	X	X
Gibraltar										
Greece	X	X		X	X	X		X		
Grenada	X			X	X	X		X		X
Guatemala	X	X	X	X	X	X		X	X	X
Guinea, Republic of	X		X	X	X	X	X	X	X	X
Guinea-Bissau	X		X	X	c	X	X	X		
Guyana	X		X	X	X	X		X	X	X
Haiti	X	X	X	X	X	X		X	X	X
Holy See		X								
Honduras	X	X	X	X	X	X		X	X	X
Hong Kong										
Hungary	X	X		X	X	X		X		
Iceland	X	X		X	X	X				
India	X	X	X	X	X	X		X	X	X
Indonesia	X	X	X	X	X	X	X	X	X	X
Iran (Islamic Republic of Iran)	X	X	X	X	X	X	X			X
Iraq	X	X	X	X		X	X	X	X	X
Ireland	X	X		X	X	X		X	X	
Israel	X	X		X	X	X		X		
Italy	X	X		X	X	X				
Jamaica	X	X	X	X	X	X		X	X	X
Japan	X	X	X	X	X	X				
Jordan	X	X	X	X	X	X	X	X	X	X
Kazakhstan	X	X	X	X	X	X	X	X	X	X
Kenya	X	X	X	X	X	X		X	X	X
Kiribati	X			X		X		X		
Korea, Democratic People's Republic of	X									
Korea, Republic of	X	X	X	X	X	X		X		
Kosovo			X						X	X
Kuwait	X	X	X	X	X	X	X	X		
Kyrgyzstan (Kyrgyz Republic)	X	X	X	X	X	X	X	X	X	X
Laos, People's Democratic Republic of	X		X	X	X	X		X	X	
Latvia	X	X	X	X	X	X		X		
Lebanon	X	X	X	X	X	X	X	X	X	
Lesotho	X		X	X	X	X		X		X
Liberia	X	X	X	X	c	X			X	X

Country	UN Agencies			World Bank Group			Regional	Bilateral		
	UN[a]	IAEA[b]	UNDP[c]	IBRD[d]	MIGA[e]	IFC[f]	IDB[g]	OPIC[h]	USAID[i]	DfID[j]
Lybia (Lybian Arab Jamahiriya)	X	X	X	X	X	X	X			
Liechtenstein	X	X								
Lithuania	X	X	X	X	X	X		X		
Luxembourg	X	X		X	X	X				
Macedonia, The former Yugoslav Republic of	X	X	X	X	X	X		X	X	X
Madagascar	X	X	X	X	X	X		X	X	
Malawi	X		X	X	X	X		X	X	X
Malaysia	X	X	X	X	X	X	X	X		X
Maldives	X		X	X	X	X	X			
Mali	X	X	X	X	X	X	X	X	X	
Malta	X	X		X	X	X		X		
Marshall Islands	X	X		X		X		X		
Mauritania	X	X	X	X	X	X	X	X		
Mauritius	X	X	X	X	X	X		X		
Mexico	X	X	X	X		X		X	X	
Micronesia, Federated States of	X			X	X	X		X		
Moldova, Republic of	X	X	X	X	X	X		X	X	X
Monaco	X	X								
Mongolia	X	X	X	X	X	X		X	X	X
Montserrat										X
Morocco	X	X	X	X	X	X	X	X	X	
Mozambique	X		X	X	X	X	X	X	X	X
Myanmar (Burma)	X	X	X	X		X			X	X
Namibia	X	X	X	X	X	X		X	X	X
Nauru	X									
Nepal	X		X	X	X	X		X	X	X
Netherlands	X	X		X	X	X				
Netherlands Antilles								X		
New Zealand	X	X		X	c	X				
Nicaragua	X	X	X	X	X	X		X	X	X
Niger	X	X	X	X	c	X	X	X		X
Nigeria	X	X	X	X	X	X		X	X	X
Northern Ireland								X		
Norway	X	X	X	X	X	X				
Oman	X			X	X	X	X	X		
Pakistan	X	X	X	X	X	X	X	X	X	X
Palau	X			X	X	X		X		
Palestinian Territories (West Bank and Gaza Strip)			X				X	X	X	X

Country	UN Agencies			World Bank Group			Regional	Bilateral		
	UN[a]	IAEA[b]	UNDP[c]	IBRD[d]	MIGA[e]	IFC[f]	IDB[g]	OPIC[h]	USAID[i]	DfID[j]
Panama	X	X	X	X	X	X		X	X	
Papua New Guinea	X		X	X	X	X		X		
Paraguay	X	X	X	X	X	X		X	X	
Peru	X	X	X	X	X	X		X	X	X
Philippines	X	X	X	X	X	X		X	X	
Pitcai										X
Poland	X	X	X	X	X	X		X		
Portugal	X	X		X	X	X		X		
Qatar	X	X		X	X		X			
Romania	X	X	X	X	X	X		X	X	X
Russia (Russian Federation)	X	X	X	X	X	X		X	X	X
Rwanda	X		X	X	X	X		X	X	X
Sahel										
Saint Helena and Dependencies										X
Saint Kitts and Nevis	X			X	X	X		X		X
Saint Lucia	X			X	X	X		X		X
Saint Vincent and the Grenadines	X			X	X			X		X
Samoa (Western)	X		X	X	X	X		X		
San Marino	X			X						
Sao Tome and Principe	X		X	X				X		
Saudi Arabia	X	X	X	X	X	X	X			
Senegal	X	X	X	X	X	X	X	X	X	
Serbia and Montenegro	X	X	X	X	X	X		X	X	X
Seychelles	X	X	X	X	X	X				
Sierra Leone	X	X	X	X	X	X	X	X	X	X
Singapore	X	X		X	X	X		X		
Slovakia	X	X	X	X	X	X		X		
Slovenia	X	X		X	X	X		X		
Solomon Islands	X			X	c	X				
Somalia	X		X	X		X	X	X	X	X
South Africa	X	X	X	X	X	X		X	X	X
Spain	X	X		X	X	X				
Sri Lanka	X	X	X	X	X	X		X	X	X
Sudan	X	X	X	X	X	X	X		X	X
Suriname	X			X	X		X	X		X
Swaziland	X		X	X	X	X		X		X
Sweden	X	X	X	X	X	X				
Switzerland	X	X		X	X	X				
Syria (Syrian Arab Republic)	X	X	X	X	X	X	X			

Country	UN Agencies			World Bank Group			Regional	Bilateral		
	UN[a]	IAEA[b]	UNDP[c]	IBRD[d]	MIGA[e]	IFC[f]	IDB[g]	OPIC[h]	USAID[i]	DfID[j]
Taiwan								X		
Tajikistan	X	X	X	X	X	X	X	X	X	X
Tanzania, United Republic of	X	X	X	X	X	X		X	X	X
Thailand	X	X	X	X	X	X		X		X
Togo	X	c	X	X	X	X	X	X		
Tonga	X			X		X		X		
Trinidad and Tobago	X		X	X	X	X		X		X
Tunisia	X	X	X	X	X	X	X	X		
Turkey	X	X	X	X	X	X	X	X	X	
Turkmenistan	X		X	X	X	X	X	X	X	X
Turks and Caicos Islands								X		X
Tuvalu	X									
Uganda	X	X	X	X	X	X	X	X	X	X
Ukraine	X	X	X	X	X	X		X	X	X
United Arab Emirates	X	X	X	X	X	X	X			
United Kingdom	X	X		X	X	X				
United States of America	X	X		X	X	X				
Uruguay	X	X	X	X	X	X		X		
Uzbekistan	X	X	X	X	X	X	X	X	X	X
Vanuatu	X			X	X	X				
Venezuela (Bolivarian Republic of Venezuela)	X	X	X	X	X	X		X		
Viet Nam	X	X	X	X	X	X		X	X	X
Windward Islands										
Yemen	X	X	X	X	X	X	X	X	X	X
Zambia	X	X	X	X	X	X		X	X	X
Zimbabwe	X	X	X	X	X	X		X	X	X

Sources of information in Table 3.2:

[a]UN. United Nations. 2005. Web site: http://www.un.org

[b]IAEA. International Atomic Energy Agency. 2004. Web site: http://www.iaea.org

[c]UNDP. United Nations Development Programme. 2005. Web site: http://www.undp.org

There are an additional 14 countries in Europe/CIS and in Asia/Pacific with UNDP projects that are not listed in the master list of receiving countries.

[d]IBRD. International Bank for Reconstruction and Development. 2005. Website: http://www.worldbank.org

[e]MIGA. Multilateral Investment Guarantee Agency. 2005. Web site: http://www.miga.org

[f]IFC. International Finance Corporation. 2005. Web site: http://www.ifc.org

[g]IDB. Islamic Development Bank. 2005. Web site: http://www.isdb.org

[h]OPIC. Overseas Private Investment Corporation. 2004. Web site: http://www.opic.gov

[i]USAID. The United States Agency for International Development. 2005. Web site: http://www.usaid.gov

[j]DfID. Department for International Development. 2001 and 2005. Web site: http://www.dfid.gov.uk

Section 4 Markets

4.1 Determining the market for sterile insects – Which pests can be controlled using SIT?

A market questionnaire was developed for evaluating the demand for sterile insects (Annex 6). It covers a range of issues that are known to impact the resource requirements and outcome of an SIT programme. Before applying this questionnaire, the species must first be evaluated.

Certain traits indicate suitability to SIT in an insect pest. Generally, only a pest with significant economic impact in various countries will be considered, due to the economic considerations of possible return from the research required to make the species successful in SIT. Developing SIT against a pest of native flora for the sake of protecting a natural resource is a fairly new application, exemplified by cactus moth (see Box 4.1). Robinson and Hendrichs (2005) cite the use of SIT for national parks or organic farms, where pesticides are not acceptable. (Although Beek 2005, suggests that some growers will not use irradiated insects for organic production.) For an insect pest to be a good candidate for targeting with SIT, it must concur with the following criteria.

4.1.1 Biological criteria

Mating strategy

Clearly, SIT can only work with species that rely on sexual reproduction. Species that mate once, or very few times in their adult lives are particularly appropriate to SIT. If a wild female mates singly with an irradiated male, her entire fecundity will be compromised. If she also mates with one or more wild males, the compromised sperm of the irradiated male will be either diluted, or selectively rejected. Species with other mating strategies are controlled by SIT, but the approach becomes less effective when a female has multiple matings and can selectively use the fertile sperm regardless of the order in which the mating occurred. The difficulty from the trait not uncommon among insects of storing sperm over time also reduces effectiveness of SIT. Lance and McInnis (2005) discuss in more detail the mating systems and post-copulatory factors that influence the success in applying SIT against a new species.

Narrow host range

Insects with the ability to subsist on many host plants or animals can use these to seek refuge outside the agricultural or treatment area and thus remain available to reinfest vulnerable crops. A narrow range of hosts minimizes this challenge, as once a population is eradicated or substantially reduced, reintroduction from refugia is a minor risk.

Dispersal ability

Insect species that disperse over very wide distances may not be appropriate for SIT unless it is carried out for suppression in place of on going pesticide applications. In such a situation, migration or introduction of gravid females or breeding populations through trade or unintentional transport will remain a source of introductions. Other steps to prevent reintroduction will be needed. For the same reason, SIT is useful in situations in which natural barriers prevent dispersal that would otherwise occur. This approach may be used for area-wide control aimed at area freedom (rather than national or ecosystem-wide eradication). SIT can be used with quarantine methods to provide a barrier between vulnerable areas and sources of infestation.

4.1.2 Technological criteria

Mass rearing and laboratory production

To produce the high numbers of insects required for an SIT programme an insect must be amenable to mass rearing techniques (Lance and McInnis 2005). There are many components that contribute to this suitability, such as the use of **artificial diets**.

Mass rearing requires that insects can be kept at **high density** and remain unaffected. Along with the risks of rapid disease spread within laboratory populations, space restriction in this manner can have both developmental and behavioural effects such as reduced ability to fly and disperse on release and reduced mating competitiveness.

In order to release large numbers of irradiated insects at the appropriate field time and in the appropriate location, the species must be amenable to **storage and transportation** (Parker 2005). The possibility of inducing developmental arrest, usually by low temperature or low oxygen regimes during the pupal stage, is another highly favourable trait that can facilitate distribution of the sterilized individuals.

Genetic strains

Most insect pests have substantial amounts of **genetic variability** across their range and laboratory populations should ideally reflect this. Species with insignificant variation will be less costly to rear, since mating incompatibility upon release will not be a problem.

Populations that can be induced to produce some trait that makes it easy to eliminate the male or female offspring, can be very important as they halve the costs of sterilization, shipping and release. Production of a single sex also increases the effectiveness of released insects by avoiding sterile female by sterile male matings in the field (Franz 2001 and 2005).

Radiation biology

Prior knowledge of the radiation doses required to produce immediate or F_1 sterility in a species is very useful (Bakri et al. 2005). The dosage must be sufficient to induce chromosome abnormality in the sperm or eggs without affecting the viability of the somatic tissue or the behaviour of the individual. Males and females of a given species often require different doses for effective sterilization. Irradiation of the insect whilst in the pupal stage is most practical as at this point they are immobile and easily transported and treated at high densities. The radiation dose must not affect the subsequent transition to the adult form and the irradiated insect must be benign in the ecosystem. This latter requirement is extremely important for insects that are vectors of disease and it must be ensured that irradiation does not enhance their ability to transmit to either plants or animals.

Detection and monitoring

The ease with which pest populations can be monitored prior to, during and subsequent to an SIT programme is a significant factor (Vreysen 2005). Monitoring tools and labour must be available to first indicate and then delineate infestation, to coordinate sterile insect releases with natural population mating times, to assess the progress of suppression/eradication and to refine released insect numbers. Cryptic insects, which are indirectly monitored by signs of their presence rather than direct trap capture, are less suitable to SIT.

Viability of control options
Other control options for the pest species may exist, including mating disruption, biocontrol, chemical control and biotechnologies. In order for SIT to succeed, there is generally some reason or motivation for changing to the use of sterile insects away from the status quo. For example, if the pest species has developed resistance to pesticides there is a definite advantage to using SIT over chemical controls. The loss of registration of a pesticide is also reason to seek options including SIT. If a viable control option is in place, however, there is less motivation to adapt to SIT.

Integration with other control strategies
Where other components of an Integrated Pest Management strategy are available, their integration with SIT to form a biological control package is highly desirable. Releases of specific parasitoids and pathogens can enhance the efficacy of an SIT programme by attacking remaining viable offspring. In fact, almost all programmes incorporating SIT rely on other control options in addition, either simultaneously or sequentially as the population is reduced.

Other factors that influence the suitability of using SIT for a particular pest species are not necessarily biological. Factors such as economic or social importance of the hosts of the pest are key, as shown in Table 4.1.

Table 4.1 Ranking of factors influencing the suitability of SIT for controlling a species: the example of setting priorities for research among moth pests (IAEA 2000)

	Global importance	Key pest	Economic importance	Mass rearing	Radiation biology	Migration	Potential for Reinfestation	Grower buy-in	Host range	National/ International support	Monitoring tools	Total	Rank	Mating disruption	Biocontrol	Chemical control	Biotechnologies	Others	Control Options Total
Codling moth	4	4	4	4	4	4	1	3	4	3	4	39	***1***	2	2	3	0	1	8
Grape berry moths	4	4	4	2	2	4	4	3	4	3	4	38	**2**	3	3	4	0	0	10
Pink bollworm	3	4	4	4	3	1	1	3	4	2	4	33	**3**	1	1	4	4	0	10
Oriental fruit moth	4	4	4	3	3	4	0	3	1	3	4	33	**3**	3	2	3	0	0	8
DBM	4	3	4	2	3	2	1	2	3	2	4	30	**5**	1	3	2	0	0	6
Sugar cane borer	3	4	2	2	2	2	2	3	4	3	2	29	6	0	3	1	0	0	
Angoumois grain moth	4	2	2	4	2	2	0	3	3	3	4	29	6	0	0	3	0	0	
Carob moth	2	4	3	2	2	3	2	3	4	2	1	28	8	0	1	0	0	0	
Peach twig borer	4	3	2	0	1	4	0	2	4	3	4	27	9	3	0	3	0	0	
Pine shoot moth	2	4	3	0	1	1	2	3	4	2	4	26	10	0	3	3	0	0	
False codling moth	3	4	4	3	2	0	0	3	1	2	4	26	10	1	3	2	0	0	
Gypsy moth	3	3	2	3	3	1	0	1	2	3	4	25	12	0	3	2	0	0	
Helicoverpa spp.	4	3	4	3	4	0	0	1	0	2	4	25	12	0	2	3	4	0	
Carposina niponensis	1	4	4	0	1	4	1	2	4	1	2	24	14	0	3	3	0	0	
Spodoptera	4	2	3	3	4	0	0	1	0	2	4	23	15	0	3	3	3	0	
Asian corn borer	1	3	3	3	3	0	0	1	3	2	4	23	15	0	1	2	1	0	
Cactus moth	1	4	3	2	1	4	3	2	1	1	1	23	15	0	2	1	0	0	
Asian gypsy moth	2	2	3	2	1	0	0	1	2	3	3	19	18	0	0	2	0	0	
Chestnut leaf miner	2	1	2	0	1	0	0	1	4	2	4	17	19	0	1	3	0	0	

4.1.3 Favourable socio-economic conditions

Clear beneficiaries willing to pay

As with any area-wide programme that may replace efforts of individual growers or communities, SIT requires the support of the grower group, local herdsmen, community health organization or other stakeholders. For this reason, the level of organization of the affected industry or other impacted sector is critical to the success of the programme. This is not only for purposes of funding, but also for cooperation in the successful implementation of the SIT programme (Dyck et al. 2005a).

If the local, regional, national or even international government or public sector is involved in the programme, long-term support is necessary. Benefits from SIT will not be fully realized if a programme does not enjoy continuity in political support. While political changes may occur, the political will to carry out such a programme is often based on the perceived demand from the industry or other stakeholders. A continued commitment is especially important when attempting to eradicate a widely-dispersed population, as this requires a systematic approach creating temporary small pest-free areas and buffer zones until the entire campaign is complete (Henrichs et al. 2005).

The SIT may be chosen over other control options increasingly in the future as the secondary costs to the environment are more often considered and more fully calculated in pest control decision making (Quinlan and Larcher 2007). In this case, the beneficiaries may be society at large.

4.1.4 Administrative capacity

Finally, SIT can only be applied when administrative capacity exists (Dyck et al. 2005b) – either through a standing institution or on a project basis. This administrative capacity does not have to be entirely local. International experts may be contracted or provided through bilateral cooperation, as well as through the IAEA technical assistance programmes. Local political will and interest in learning is essential, however.

Lindquist (2001) identifies the requirements for any area-wide control programme to include:

- the selection of an appropriate insect pest species;
- extensive ecological data on the target species;
- control methods applicable for area-wide control of the species;
- support of the stakeholders to accept and finance the programme;
- a professional business protocol for the programme;
- an effective organization to manage the programme;
- a system for evaluation of the programme;
- research support for the programme.

Each of the above is required for a successful SIT programme. In addition, there must be a **steady supply of quality sterile insects at a cost appropriate to the economic return**, (or established value in the case of ecological protection) of the treated area (Mumford 2005; Dowell et al. 2005). This generic business plan focuses on the cost-effective production of quality sterile insects. The rest of Section 4 attempts to summarize and estimate the existing and medium term demand for sterile insects for use in SIT.

4.2 The market for sterile fruit fly species

The decision to control significant fruit fly pests is often made easier with data from cost benefit analyses to reveal the potential impact of control programmes. While traditionally the direct beneficiaries, generally fruit growers, were considered in this decision process, increasingly the indirect costs and benefits of various control options are being taken into account (Quinlan and Larcher 2007). Enkerlin (2005) provides case studies on the economic impacts of various preventative, suppression, eradication and containment programmes against fruit fly pests around the world.

4.2.1 Medfly

The Mediterranean fruit fly or Medfly (*Ceratitis capitata*) is considered one the most damaging plant pests in the world. Because this pest is limited in distribution, quarantine regulations against the species are very common and affect trade in a number of fruits.

Common hosts

Common hosts include citrus, coffee, guava, mango, papaya, plum, peach and other stone fruits. The list of hosts includes hundreds of plants, however, and the pest is well able to survive on less favoured hosts when the primary ones are not available. Liquido et al. (1995) reviewed literature on Medfly hosts and found that many references were early and not substantiated by later, better-documented and presumably more accurate research. An extensive bibliography covering 1912 to 2001 lists research papers on mating behaviour, ecology, mass rearing, sterilization, diet, hosts and other topics regarding Medfly appears on the Citrus Research and Education Center Web site (CREC 2002).

Past, present and possible future distribution of Medfly

In the distribution map in Figure 4.1 (prepared for Nugent et al. 2001), countries are shown as a whole if there was a population of Medfly in any part of the country (with the exception of the USA where Hawaii has suffered an infestation since 1910). The African origins of the species are clear from the distribution map, although it has been established in South America for some time. The eradication of Medfly from Mexico and from Chile is shown by the yellow cross at the southern-most point and northern area, respectively, where a barrier of sterile insect releases stops natural re-invasion. Belize has been considered Medfly free since 2001, as has the Department of Peten in Guatemala. The entire Patagonia region of Argentina was recognized by the USDA as free from Medfly and *Anastrepha* spp in 2005. A fruit production oasis in the central part of the Mendoza Province ha also been declared Medfly free and efforts in other areas in Argentina, such as San Juan Province, continue.

Other sites where eradication of Medfly has occurred are shown with yellow crosses in the continental USA. According to the Florida Department of Agriculture and Consumer Services (FDACS 2002), Medfly outbreaks occurred in Florida from April 1929 to July 1930, April 1956 to November 1957, June 1962 to February 1963, June to August 1963, and 3-14 August 1981; in Texas from June to July 1966; and in California intermittently since September 1975. These are well-documented and studied examples of areas with repeated infestations surrounding sites of high international traffic in air and sea cargo. In both cases, on-going preventative releases are employed.

As shown in Figure 4.1, distribution of Medfly does not include Jamaica, contrary to some historical publications, and therefore there is no incidence of Medfly in the Caribbean. The Rural Agricultural Development Authority (RADA), the Jamaican Ministry of Agriculture

(JMOA) personnel and USDA/APHIS personnel jointly maintain a trapping programme for Exotic Fruit Flies that includes the Medfly (using Jackson traps) and for other fruit flies (using McPhail traps), mostly *Anastrepha* spp. There are more than 80 Jamaicans involved with the trapping programme in all fourteen counties of Jamaica (Flores 2002). Accordingly, introductions into Florida have been traced to shipments of commodities from other regions, often air cargo, rather than migration or artificial movement from the neighbouring Caribbean.

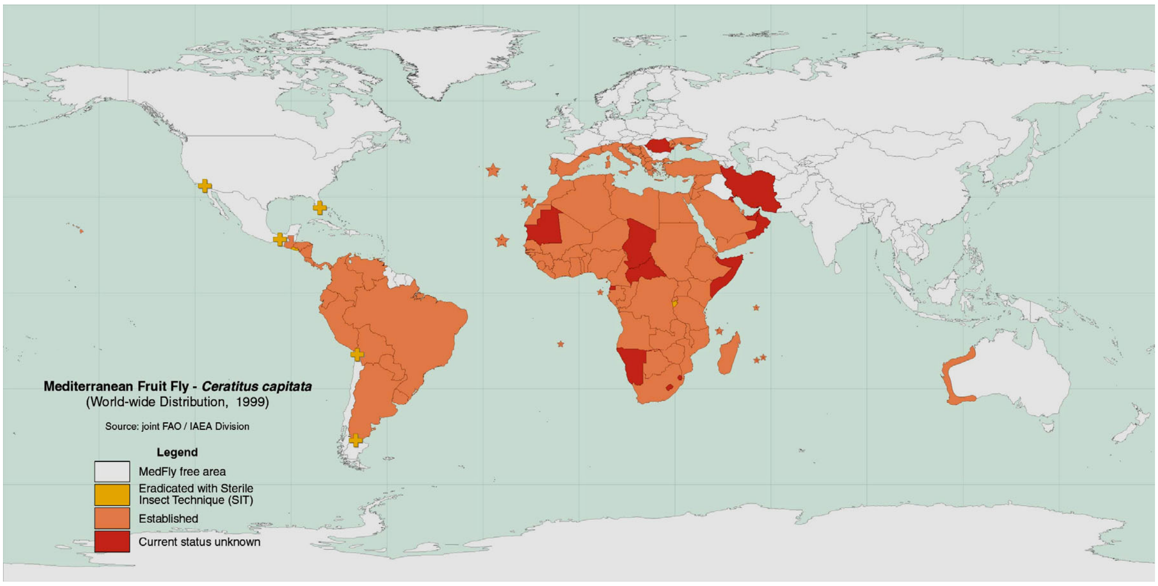

FIG. 4.1 Map showing the incidence of Medfly in 1998 and locations where it was formerly established but has since been eradicated (crosses).

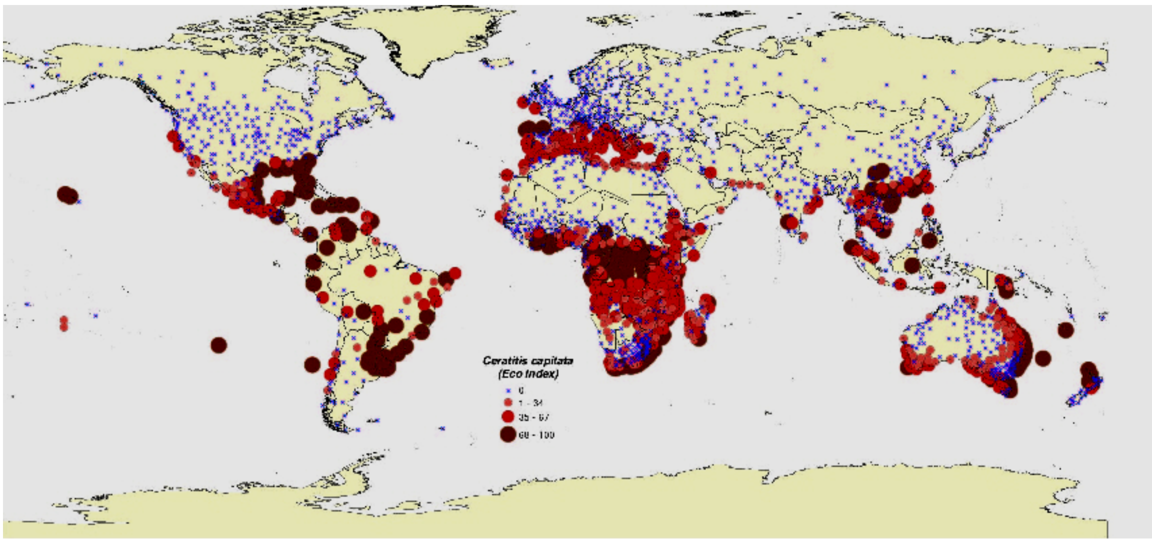

FIG. 4.2 Climex prediction of possible distribution of Medfly (Ceratitis capitata) if introduced to all susceptible areas.

Bermuda's eradication is not marked on this map, as it was not achieved using SIT (see below for details). Also not represented in this Figure are outbreaks of Medfly in South Australia, which most recently have been eradicated using SIT. The distribution of Medfly remains in flux, as new outbreaks occur and control programmes achieve pest free areas.

The distribution map shows the importance of this one species as a plant pest. Even more striking is the map (Figure 4.2) of where Medfly is projected to be able to survive if introduced. This shows the vulnerability of much of SE Asia, New Zealand and parts of the Indian subcontinent where Medfly is not currently established, in addition to the entire Caribbean and many of the areas of North America where the pest had been introduced but was since eradicated. This potential distribution area increases even further if global warming trends are factored in.

Improved detection

As with all pests, the success and cost-effectiveness of control of Medfly incursions or outbreaks and the reliability of distribution or delimitation studies depends on detection. In the past the most widely used attractant for Medfly was trimedlure, which was developed by USDA Agricultural Research Service (ARS). More recent developments by the USDA/ARS culminated in a new isomer compound, called minus-ceralure, that is four to nine times more effective and thus will greatly enhance detection, however, this is not yet in use in operational programmes (McBride and Wood 2000). Currently some of the main surveillance programmes such as the ones in the USA, Mexico, Guatemala and Chile use a dry synthetic food lure which is female biased (Biolure). This lure is more efficient in terms of early detection and its use for detection trapping is recommended in programmes that release only males as trimedlure baited traps catch to many of the more active sterile males being released.

SIT programmes against Medfly

Mass rearing, research and control programmes of Medfly are generally more advanced than for other fruit fly species, due to the many years of experience with this species. Information about sterile Medfly production facilities appears in Section 5.

The Medfly Eradication and Barrier Programme in Mexico and Guatemala is the longest running and largest, and thus serves as a model for other programmes. Since 1978 SIT was used to push the pest's population presence down from the now pest free areas of Mexico to the centre of Guatemala. The Governments of the USA, Mexico and Guatemala finance the programme, referred to by the Spanish common name of Medfly, Moscamed. The USDA/APHIS has estimated that if Medfly became established in the continental US, it would cost US$1.5 billion a year in agricultural losses (García 2001). The costs of fighting Medfly in California alone are around US$500 million over the past 25 years. A single eradication campaign in Florida (Tampa Bay) lasted nine months and cost US$25 million (Wood and Hardin 2000). The USDA co-funds control programmes with individual states in continual efforts to prevent the entry and establishment of Medfly.

Under this programme, Mexico has achieved full eradication and Guatemala has areas recognized as Medfly free. The Department of Peten in Guatemala and the country of Belize gained Medfly-free status in 2001, which opened up the export market for papaya, for example, since this fruit is not a host to other species of fruit flies that continue to infest those areas (i.e. *Anastrepha* spp.).

Over the years there has been pressure to move the barrier south beyond Guatemala, as was the original intention of the programme, and to address the fruit fly problem in Honduras and Nicaragua. With coordination by OIRSA (the Central American Regional Plant Protection

Organisation), a more regional approach to control of *Anastrepha* spp. as well as Medfly control has been explored (IAEA 2001j). Finally, after the frustration of not gaining regional freedom from Medfly, there are fruit fly free and low prevalence production areas operating in Guatemala, El Salvador, Honduras, Nicaragua and Costa Rica. Nicaragua and Guatemala are already exporting bell peppers and tomatoes from these areas to the USA and it is expected that Costa Rica will start soon (Reyes et al. 2007).

Argentina's SIT programme for eradication and control of Medfly started over ten years ago. As noted above, Patagonia now has fruit fly free status and other parts of Argentina are under suppression or approaching eradication levels. The long term experience with Medfly has led many countries to consider beginning a SIT programme. In the future these countries may be customers for private production facilities, as capital costs are too high for individual programmes to construct their own production facilities in many cases.

A more recent SIT programme is the sterile Medfly release in South Africa. South Africa is the only Southern Hemisphere deciduous fruit exporting country that is neither Medfly free, nor nationally engaged in an eradication programme (Allsop and Eyles 2002). This leaves the region at a disadvantage for Northern Hemisphere winter markets, which prefer no pesticide residues. Therefore with interest from the growers, the ARC-Fruit, Vine & Wine Research Institute began collaborating with the IAEA to produce 3 to 4 million sterile Medfly males per week for release in a pilot project in the Hex River Valley. The privatization and expansion of this programme is described in Section 5. There is demand for larger scale production and possible future plans for mass rearing and sterlizing the Natal fruit fly, *Ceratitis rosa*, or even codling moth under the same programme.

The citrus growing areas in Spain had progressed from years of pesticide applications by the calendar, to observing economic thresholds before applying control measures and finally to the current attitude which embraces IPM, particularly in Valencia, Andalucia, Murica and Cataluna (Coscollá 2000). In early 2000, a summary of the use of IPM in citrus groves considers the use of SIT for Medfly control, but still mentions concerns about its efficacy, given the extension, density and diversity of the plantations and the cost. In 2001/2002 the interceptions of Medfly in Spanish citrus, despite cold treatment, was linked with high levels of Medfly in the field. This led to the USA closing its market to Spain temporarily and prodded interested parties into taking the steps to switch to area-wide suppression. Confidence also rose, and a production facility was constructed in Valencia to provide sterile Medfly to growing areas of Spain. A Cleanfruit report (Cleanfruit 2006d) discusses the present situation with Medfly control in citrus in more detail.

Other regions, on the other hand, appear less likely to proceed with SIT than was expected in the 1990s. The 1992 study of the Maghreb (Rohwer et al. 1992) carried out under the auspices of the IAEA outlined the feasible steps for a field campaign that would eradicate Medfly from Northern Africa. The programme would have taken 12 years (3 in preparation and 9 in implementation) with subsequent years of quarantine measures required to prevent re-invasion. Nine zones were defined covering Libya (2500 km^2), Tunisia (5250 km^2), Algeria (3 zones of 2700 km^2 each) and Morocco (4 zones of 3900 km^2). The programme was to move on to a new zone each year after eradication, therefore with a total requirement of 50 000 sterile male Medfly per km^2, the height of demand would have been for approximately 262.5 million sterile flies per week.

The subsequent economic review of this proposal provided a more precise land area for treatment, reducing the projected demand for sterile flies somewhat. The evaluation of SIT eradication compared to other options showed that the final annual net benefit was greatest if eradication were achieved (Mumford et al. 1995). The resources and logistics for this ambitious possibly 15-year programme, estimated to total US$350.9 million (per the 1992 study), have proved to be prohibitive, however, along with the political withdrawal of Libya from this effort. Given the present level of interest, any use of SIT in the region is expected to be limited to suppression in citrus areas in Tunisia and Morocco for some years to come. Possible scenarios for suppression programmes in Tunisia and Morocco are provided in Annexes 3 and 4 of this report.

Table 4.2 Current and probable demand for sterile male Medfly for use in SIT
(2006 information, estimated from a variety of sources, including those cited in Section 4.2.1 as well as Clark et al. 1996; and FDACS 2001)

On-going demand	
• **Suppression**	
Valencia (Spain)	Began suppression programme in citrus areas in 2004 with 20 to 30 million/wk from Argentina. By end of 2006, will switch to local source of sterile flies for larger treatment area.
Other citrus areas in Spain	A large market that may materialize with the experience of Valencia and greater supply of sterile flies.
Madeira (Portugal)	1997 to present. Sourced from Madeira.
Algarve (Portugal) - see Annex 2 for details and probability of uptake.	Economic study complete, possible start of SIT in 2007/8.
Ribatejo and the Oeste (Portugal) - see Annex 2 for details and probability of uptake.	Economic study complete, uptake of SIT now (2006) seems unlikely.
Hex Valley (South Africa)	1993 to present, small area suppression plan. Sourced locally from pilot facility, with supplement from Guatemala when needed.
Other areas in Western Cape (S Africa)	Began in 2003, with local facility and Guatemala supplying additional to local production. Construction of larger local facility delayed.
Cap Bon (Tunisia) – could be expanded to other zones. See Annex 4 and this Section for comments.	Small scale programme from 2003, sourcing from local pilot facility.
Berkhane (Morocco) – Morocco could also choose eradication with an on-going barrier of sterile Medfly along the border with Algeria.	No concrete plans, but could start at any time that work is organized. See Annex 3 for possible scenarios.
Arava Valley (Israel/Jordan)	Since 1998. North Galilee added since. Sourced from Madeira originally, then Guatemala and now from Bio-Fly in Israel.
Other parts of Israel	May have greater coverage when the expansion of Bio-Fly occurs.
Egypt	Interest from commercial sector. May be delayed by focus on control of *Bactrocera zonata*.
Turkey, Morocco, Tunisia, Spain, Crete (Greece) Croatia, Corsica (France), Cyprus, Sicily (Italy) Israel, Portugal	Locations where preliminary planning has taken place with support from the EU CLEANFRUIT project.

Table 4.2 (Continued) Current and probable demand for sterile male Medfly for use in SIT
(2006 information, estimated from a variety of sources, including those cited in Section 4.2.1 as well as Clark et al. 1996; and FDACS 2001)

• Preventative or barrier release	
Los Angeles area, California (USA)	Since 1996, sourced from Guatemala. Formerly supplemented from Hawaii.
Tampa south to Sarasota, Florida (USA)	Since 1998, sourced from Guatemala.
Central Miami, Florida (USA)	Since 1998, sourced from Guatemala.
South Australia around Adelaide (Australia)	2001, sourced from Western Australia.
Arica (Chile)/Southern Peru – Tacua and Moquegua Provinces (Peru)	Since 1995. Barrier for maintaining Chile Medfly free. Sourced from Chile.
Guatemala (as of late 2001, the Peten Department of Guatemala is declared free of Medfly)	For over 20 years. Barrier for Mexico and USA, possibility of moving the barrier south to another country. Sourced from Guatemala and Mexico.
Chile	Preventative release in Arica since 2005.
Eradication (limited number of years)	
• Eradication of established population	
Mendoza and San Juan Provinces (Argentina)	Since 1992. Aimed at area-wide freedom/eradication (rather than national eradication). Sourced locally.
Neuquen and Rio Negro Provinces (Argentina)	Since 1997 completed in 2006. Same objective as above. Sourced from Mendoza.
Western Australia	Pilot programme carried out in Broome. CBA completed in 2001. Unlikely to be funded on its own merits, but may garner support as South Australia faces more incursions.
Azores (Portugal)	Low number required, possibly sourced from Madeira. Eradication could be achieved, but suppression might also be considered.
• Could be eradicated for environmental reasons	
Seychelles -- If the present control programme for the melon fruit fly (*Bactrocera cucurbitae*) achieves eradication, there will be only one spp of quarantine fruit fly, unlike other Indian Ocean countries.	Due to the present level of awareness of invasive alien spp, it is possible that interest in eradication of Mefly could develop.
Rota, Northern Marianas (US territory)	This is the only infestation listed for the Pacific, other than Hawaii, so that eradication may be sensible.
• Eradication if incursion/outbreak occurs	
California (USA)	Countries and states that would want to maintain their status as free of Medfly and that are familiar with and open to use of SIT.
Florida (USA)	
Mexico	
Caribbean countries	
Chile	
Australia (outside of W Australia)	
• Eradication if incursion/outbreak occurs (but unlikely to use SIT)	
Japan (in the zones where it could survive winter)	Countries that may prefer other methods, although capable of using SIT.
Chinese Taipei – Taiwan	
New Zealand – may consider SIT now, based on successful use of this method for the painted apple moth	
Bermuda	Countries small enough to make other methods effective.
small island nations	
This information is difficult to verify and is continually changing. The Table is intended to show trends rather than guaranteed markets.	

A pilot level SIT control programme was conducted in the coastal plain east of Bizerte in 1970–71 by the Tunisian Government and USAID. A total of 57 million sterile Medfly in 1970 and 175 million sterile Medfly (both sexes) in 1971 were produced in Tunis and released, in conjunction with cultural and chemical control measures (FAO 1995). The results were satisfactory but nothing more was done until in 1993-94 a pilot test was carried out in Southwest Tunisia, in the seven mountain oases of Tozeur Governorate. In this case 71 million sterile male Medfly were produced in Seibersdorf, Austria, by FAO/IAEA and shipped to Tunisia for weekly release from February to early October. The results of this trail were striking, effectively reducing the Medfly population below a notable damage threshold (FAO 1995). Once the production capacity is reached at the new Tunisian Medfly facility, similar scale SIT programmes will began again. Plans for sterile Medfly release in Tunisia are discussed in Annex 4.

Eradication with insecticides

Over the years, methods other than SIT have been used for control and even eradication of Medfly. For example, according to a review of the Medfly in Bermuda (Hilburn and Dow 1990) this species first arrived in Bermuda in the late 19th century. It mainly infested banana plants (*Musa cavendishii*) and the broad bean (*Vicia faba*). The first concerted attempt at eradication occurred in 1907, when all Surinam cherry, orange and peach trees and unripe fruit from other hosts were destroyed. However this attempt failed, as some inhabitants hid host trees in their gardens, showing once again the importance of community support. A second campaign was initiated in 1957, using Steiner-type traps (angelica oil was used as an attractant, and DDVP [dichlorvos] as a toxicant). At this time, population levels were high, peaking in mid-June (mean 936 flies/trap). The 18 orchards were sprayed with a combination of malathion and protein attractant every 8-10 days for around 5 months.

The following year, trapping and foliar sprays were done in conjunction with ground sprays of the pesticide dieldrin. Trapping showed a huge population drop; most that were present came from just a single site. In 1962, trapping was increased and only one fly was recovered (Hilburn and Dow 1990). Bermuda's Department of Agriculture was preparing to initiate a new eradication programme using SIT, but this was not implemented due to conclusive results from other methods of control. The continuing absence of Medfly in Bermuda was later confirmed. In 1987 an intensive trapping programme (USDA sponsored) was completed in all areas of Bermuda. No flies were caught and Bermuda was declared fruit fly free, although a continuous trapping programme takes place to monitor the situation (Hilburn and Dow 1990).

Isolated, island nations such as this one can consider alternative methods when the outbreak is limited and detected in time. For those locations with repeated introductions or low-level endemic populations in urban areas or other non-commercial locations difficult to treat, SIT has proven ideal.

Another common method for control of Medfly, particularly in high populations, is aerial spraying of malathion. This pesticide is generally mixed with a protein bait to attract Medfly as a food source. Increasing concerns over the safety of malathion have led some programmes to abandon its use. More pressing is the fact that agrochemical companies may not re-register the use of malathion for fruit fly control due to high costs and concerns over opposition. Baited traps, as were used in Bermuda, are often used for both control and detection. These enclosed systems are much more acceptable to the public and continue to be employed throughout the world. In September 2006, however, the decision was made to discontinue any type of use of malathion throughout the European Union (Cleanfruit 2006c and 2006d).

A more environmentally acceptable insecticide called spinosad, a product of the soil bacterium *Saccharopolyspora spinosa*, has been considered a possible substitute for malathion. The USDA has evaluated spinosad against malathion and phloxine B, another promising alternative, in terms of efficacy against Medfly, but also impacts on non-target organisms. While malathion was more effective in trials in Hawaii, both spinosad and phloxine B gave good performance and had little impact on the indicator non-target organism which has been particularly susceptible to malathion (Wood and Hardin 2000).

Similarly promising results have been achieved with spinosad against the Mexican fruit fly and Caribbean fruit fly (see 4.2.2 for more on these species). The combination of spinosad plus SIT has the potential to suppress populations below those achieved through applications of malathion alone (Wood and Hardin 2000).

4.2.2 *Anastrepha* spp

Anastrepha is a fruit fly genus consisting of 183 known species, although only six are considered to be of significant economic importance. It is a major pest causing serious damage in citrus crops, mangos, guavas and other subtropical fruits. This genus is indigenous to the Americas, presently with no distribution outside the Western Hemisphere. Of the many species of *Anastrepha*, *A. ludens* (Mexican fruit fly) and *A. obliqua* (West Indies fruit fly) are recognized to be of most economic importance in Mexico and some Central American countries. The species *A. obliqua* together with *A. suspensa* (Caribbean fruit fly) are of major importance in some Caribbean countries. Whereas *A. fraterculus* (South American fruit fly) and *A. obliqua* are of highest economic importance in South America (IAEA 1999a). Other *Anastrepha* spp of economic importance inlcude *A. serpentina* (sapote fruit fly), and *A. striata* (guava fruit fly) (Enkerlin et al. 1989).

Production of sterile *Anastrepha* spp
SIT control programmes for *A. ludens*, *A. obliqua* and *A. suspensa* have been in operation for a number of years — more than 40 years in the case of *A. ludens*. Research and field trials are underway for *A. fraterculus*, *A. serpentina* and *A. striata*.

The corner stone of the Mexican control programme is a complex of two mass rearing and sterilization facilities, shown in Figure 4.3. The first component was build in 1978 and officially named in 2003 “Jorge Gutierrez Samperio” after a former General Director of Plant Protection in Mexico who was instrumental in the creation of the Mexico-USA Programme for Medfly Eradication referred to as “Moscamed”. This, is a single unit facility. The other was build in 1993 and officially named in 2003 “Dieter Enkerlin” after an entomologist who had great influence in the adoption of integrated pest management practices (including fruit flies) in Mexico and the whole of Latin America. This is a modular facility that produces two major *Anastrepha* species, namely *A. ludens* and *A. obliqua*. The Medfly facility has been producing sterile Medflies for release for more than 28 years at the border of the state of Chiapas, Mexico, and Guatemala as part of a containment barrier to prevent the northern spread of the Medfly (see Section 4.2.1 above).

In December 1993, construction of the new modules for production of *Anastrepha* spp and parasitoids was completed (Rull G. et al. 1996). By April 1994, 50 percent of the projected production of *A. ludens* was regularly achieved. Colonization of *A. obliqua* began in 1992, but it was some years before mass scale production was accomplished. A colony of *A. serpentina* is also established and ready to be up-scaled for mass production if required. Efforts to colonize *A. striata* continue, however, developing a suitable diet and oviposition system for mass production has been in this case a difficult task.

FIG. 4.3 The Dieter Enkerlin plant for production of Anastrepha and parasitoids next to the Jorge Gutierrez Samperio facility for Medfly production. Metapa, Chiapas, Mexico.
(Source of photo: Campaña Nacional Contra Moscas de la Fruta (CNCMF), Dirección General de Sanidad Vegetal (DGSV), SAGARPA, Mexico).

The South American fruit fly, *A. fraterculus* (Wied.), remains challenging to mass rear for SIT. The only production facility is in Peru. In 1997 the Joint FAO/IAEA Division, with the support of the Agricultural Service (SAG) of Chile, assembled scientists and plant protection experts from throughout the American continent to discuss advances on the South American fruit fly and relevant knowledge from other *Anastrepha* species (IAEA 1999d). At the Entomology Laboratory in Seibersdorf, Austria, improvements in the quarantine facilities were made in order to comply with national requirements for importation of colonies of *Anastrepha spp*, a genus exotic to Europe (IAEA 2001g). In Seibersdorf, an improved artificial diet for *A. fraterculus* has been developed (Braga et al. 2006) and cross-mating studies between different geographic populations have been conducted (Vera et al. 2006).

SIT programmes against *Anastrepha*

In the case of the *Anastrepha* species, sterile fruit fly releases are done in mango and citrus commercial production areas in northwest and northeast Mexico. By integrating SIT with monitoring techniques and other complementary control methods, fruit flies of economic importance have been eradicated from infested areas in northwest Mexico including the states of Baja California, Baja California Sur, Coahuila, North of Sinaloa and Sonora, which account for more then 35 000 ha of commercial plantations of citrus and mango. As a result, fruit production has increased both by eliminating direct damage by fruit flies and with the re-conversion of annual crops to fruit crops. In addition, citrus and mango are being exported to the USA without the need for a post-harvest treatment. In the northeast part of the country, in the states of Nuevo Leon and Tamaulipas, area-wide SIT suppression activities have reduced populations to low prevalence levels in more than 20 000 ha of citrus.

Table 4.3 Current and probable demand for sterile *Anastrepha* for use in SIT

On-going demand	
• **Preventative release**	
Northern Baja California (border city of Tijuana) *A. ludens* (Preventative Release Program) (USDA/APHIS, 2001/CDFA).	16 million sterile Mexflies/week (since 1995)
Texas (*A. ludens*)	Low levels of detection, is controlled in an extensive preventative release program by the state of Texas and the USDA. 30 million sterile Mexflies per week. Sourced from the facility in Mission, Texas and Metapa, Mexico.
• **Suppression of established populations**	
Mexico, Nuevo Leon and Tamaulipas	Citrus production areas of Nuevo Leon and Tamaulipas. Suppression programme since 1997. 100–150 million Mexflies per week. Sourced from the rearing facility in Metapa, Mexico.
Mexico, Sinaloa and Nayarit	Mango production area in Central and South Sinaloa and North Nayarit. Suppression Program since 2000. 100 million Mexfly and 50 million West Indies fruit fly per week. Sourced from the rearing facility in Metapa, Mexico.
Eradication (sterile fly needs limited to a number of years)	
• **Eradication of established population**	
Mexico, Tijuana Baja California Norte	Sterile flies required on a continuous basis until eradication is achieved. 20 million Mexfly sourced from the rearing facility in Metapa, Chiapas.
Mexico, Nuevo Leon	Localized 13 000 ha of citrus in General Teran, state of Nuevo Leon. 50 million Mexfly per week. Sourced from Metapa.
• **Eradication if incursion/outbreak occurs**	
Mexico; Sonora (USDA/APHIS, 2001)	World's first USDA recognized pest free zone. Continuous fruit fly surveillance year round. Sterile flies would be required to eradicate wide-spread outbreaks.
Northwest Mexico including Baja California, Baja California Sur, Chihuahua, North of Sinaloa and Sonora (USDA/APHIS, 2001; Diario Oficial de Mexico, Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion. April 17 2001)	All are certified as free areas except for the city of Tijuana. In free areas sterile flies would be required to eradicate wide-spread outbreaks.
California, USA, (*A. ludens*). Not established occasional incursions.	Monitoring using traps. Sterile flies required to eradicate outbreaks.
Texas (*A. fraterculus*). Not established occasionally detected.	Monitoring using traps. SIT not yet available.
Texas (*A. obliqua*). Not established occasionally detected.	Monitoring using traps. Sterile flies may be required to eradicate outbreaks.
Florida (*A. obliqua*). Not established occasionally detected.	Monitoring using traps. Sterile flies may be required to eradicate outbreaks.

A summary of current SIT programmes for eradication, suppression, and prevention of *Anastrepha* spp appears in Table 4.3. One can estimate demand based on a summary of these programmes.

The economic impact of this programme has been substantial. One specific example is the citrus production in the state of Sonora, one of the states in the northwest region that is certified as fruit fly free. The state grows 10 000 ha of citrus and produces over 90 percent for the export market without phytosanitary restrictions. In 6 years the total export volume has amounted to more than 130 000 mt with an estimated value of US $10.3 million. The crop generates 400 000 day-wage of work per year, equivalent to US $3.2 million (Enkerlin, pers comm 2002).

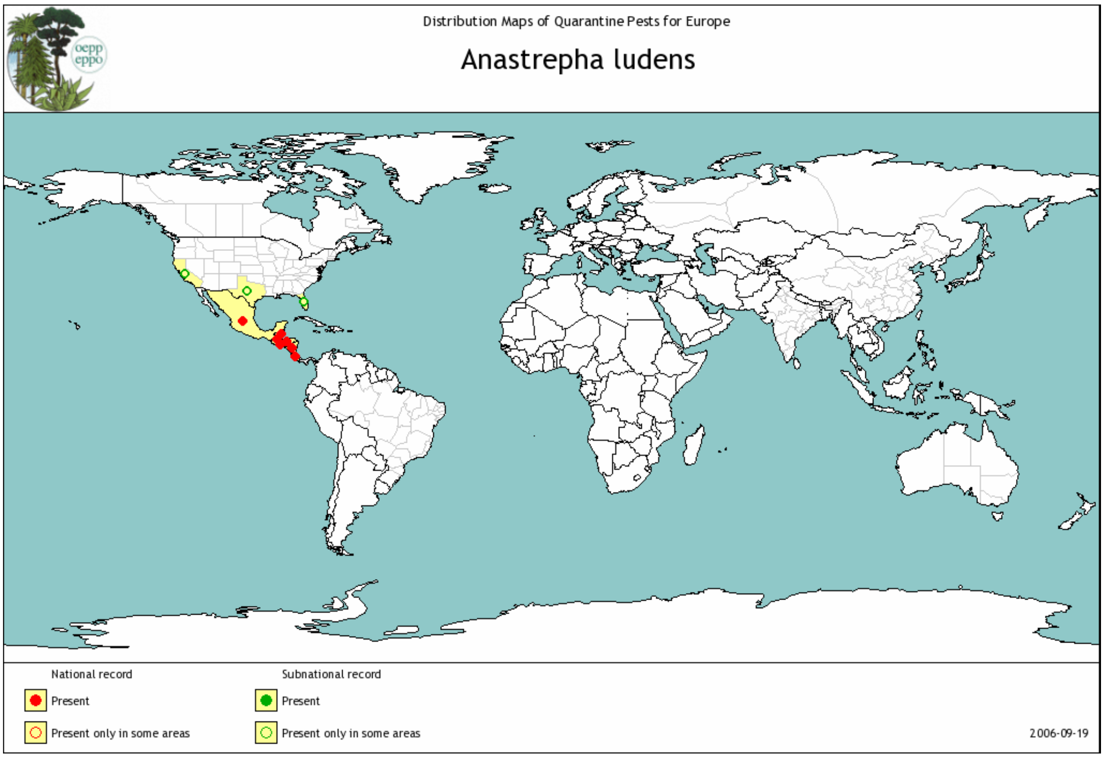

FIG. 4.4 Mexican fruit fly (Anastrepha ludens) global distribution.
(Source: EPPO website, 2006).

Effective control of fruit flies and maintenance of fruit fly free status in the northwestern states, has opened the possibility to expand in 50 000 ha the area planted with fruit crops. This will produce substantial economic and social benefit to that region in Mexico. In addition, the control of *Anastrepha ludens* in Mexico has mitigated the risk of incursions to the Southern USA, particularly into Texas and California. Establishment of the Mexican fruit fly in the US could cost US$1.4 billion in crop losses, lost export sales and treatment expenses (Heath, 1999).

A recent global map of distribution (Figure 4.4) demonstrates the success of these efforts with *A. ludens*, with most incursions of all species of *Anastrepha* into the USA now occurring in Florida or California and entering via infested cargo rather than through natural spread of populations. An improved synthetic food lure for Mexican fruit flies is now available. This will help in both detection and control of Mexican fruit fly incursions.

4.2.3 Olive fly (*Bactrocera oleae*)

The olive fly (Syns. *Dacus oleae*, *Daculus oleae*, *Musca oleae*) Gmelin (Diptera, Tephritidae) is another serious fruit fly pest, although more limited in distribution and host range than the Medfly, for example.

The olive fly attacks three species in the plant genus *Olea.* Many cultivated varieties of olive exist, each selected for fruit or oil production and regionally adapted characteristics, but the olive tree grown commercially is a single species: *Olea europaea* (syn. *O. europaea sativa*) L. (Oleaceae) (Amouretti 1988). Two wild species, *Olea europaea africana* and *Olea verrucosa*, are recognized in the genus and are native to scrubland in North and East Africa, the Middle East and in countries surrounding the Mediterranean Basin.

Distribution of olive fly

Natural spread of adults and transport of infested fruit are the primary means for spread of olive fly (CABI 2001). Dispersal can take place over substantial distances and there are reports of individuals travelling 4 km over land and 10 km over water (Sibbett 1999).

Current distribution extends beyond that shown on the map in Figure. 4.5. For example, olive fly was recently trapped in the Indian Ocean (Réunion). The known distribution in Africa includes Algeria, Angola, Canary Islands, Ethiopia, Eritrea, Kenya, Libya, Morocco, South Africa, Sudan and Tunisia. There are anecdotal reports from other coastal East African countries. Reports from the Middle East and Asia cover Armenia, Azerbaijan, Cyprus, Georgia, Egypt, Israel, Jordan, Syria, Saudi Arabia and Turkey. Pakistan and India suffer some areas of infestation (CABI 2001).

Most published reports are from the European countries along the Mediterranean as well as Portugal, Spain and even France and Switzerland. An extensive amount of the research on this pest has taken place in Greece.

The olive fly was first reported in California in 1998 and shortly after that in the olive growing regions of Baja California and Sonora, Mexico. In Florida, State and Federal agencies frequently intercept larvae and pupae in imported olives and adult flies have been noted occasionally (van Weems and Nation 1999).

Biology

In most regions there are from two to six generations of olive fly per year. Where winter temperatures fall below 5–7°C, over-wintering is by pupation in the soil with adult emergence in March to May (Northern Hemisphere). In areas where winter temperatures are higher and frosts are rare, adults can over-winter either in or outside the olive grove. The adult spends six to 14 days in preoviposition whilst the gonads mature. After a single monogamous mating (making it eminently suitable to SIT), female olive flies lay 10 to 12 eggs per day, one per fruit, and can lay up to 400 eggs in a lifetime (Sibbett 1999).

Low temperatures and poor resource availability are known to interrupt the oviposition period for up to 6 months (INRA 1998). Eggs require 2 to 16 days before hatching and larvae feed on the fruit pulp leading initially to spoilage and then to fruit drop. The larval stage can last from 9 to 40 days and pupation, during the summer months, takes place within the host fruit and can last 10 to 90 days.

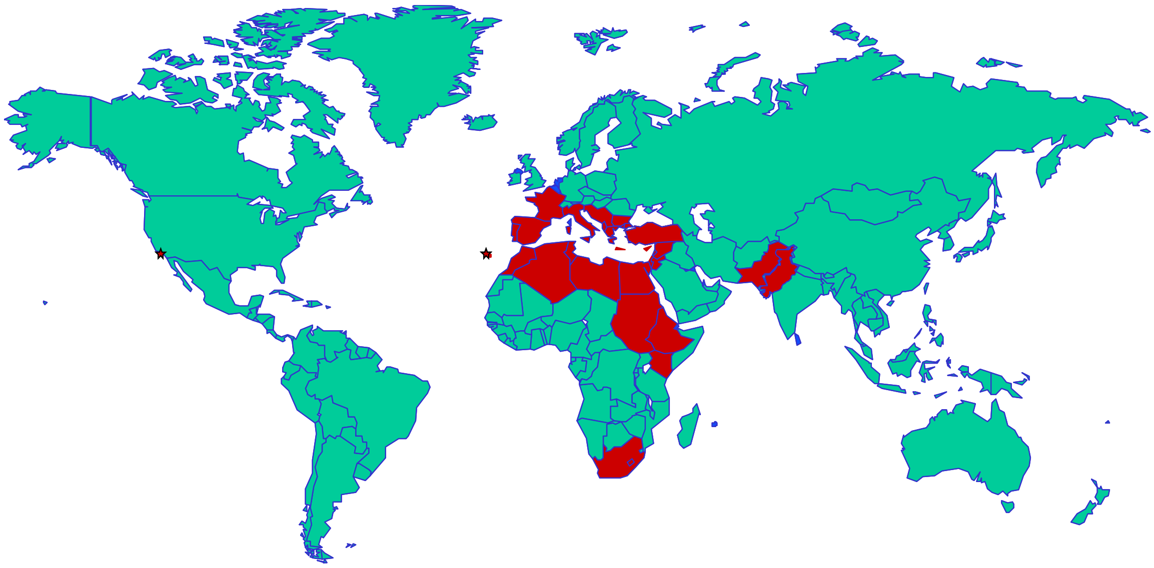

FIG. 4.5 Olive fruit fly (Bactrocera oleae)
(Source: Based on “Fruit Fly Pests Of the World” by Scientific Advisory Services Pty Ltd, sponsored by FAO/IAEA).

The lower activity threshold for adult olive flies is 15.5°C and temperatures above 38°C adversely affect both adults and larvae. Although advances are being made in the modelling of olive fly populations within California (Comins and Fletcher 1988), the variety of microclimates and temperature regimes make population predictions uncertain.

There is some evidence of genetic differentiation between laboratory and wild populations of the olive fly (Loukas et al. 1985; Tsakas and Zouros 1980) and recent work indicates that, even though gene flow is high, there may also be considerable differentiation in agriculturally isolated wild populations (Orchando and Reyes 2000).

Pest population level and damage

In endemic regions *B. oleae* typically infests 30 percent of the olive crop, but variance is high, and there are reports of near 100 percent infestation (White and Elson-Harris 1992). The factors contributing to the variance in attack rate are poorly understood, but are thought to be dominated by size and water content of fruit — large, table selected olives being favoured hosts. Olive fruit crops are thus of particular concern as either oviposition scars, emergence holes or contained larvae cause substantial economic damage by preventing crop sale from as little as a 1 percent infestation level. In oil crops, storage of infested fruit prior to processing can lead to an increase in oil acidity of 12 times normal levels (Rice 2000; White and Elson-Harris 1992).

The causal agent of olive knot disease, *Pseudomonas savastanoi*, is a symbiont of the olive fly. This bacterium is required by both adults and larvae in order to digest food. It is not certain whether the fly vectors this disease, which can cause cankers, bark splitting and rupture of host vascular tissue. Oviposition and larval feeding also permit incursion of secondary infections of detrimental bacteria and fungi.

Suitability of olive fly for control with SIT – the Greek experience
A recent report (Economopoulos 2002) summarizes the olive fly SIT experience in Greece to date. Investigations began there in 1959 and ran for 20 years. The major successes and failures in the components of the project there are described here.

Artificial rearing diets – The development of a larval artificial rearing diet that would cheaply substitute for olive fruit proved challenging. The use of preservatives and antibiotics to prevent spoilage of the medium led to a deterioration in the quality of the flies and their symbiotic microorganisms and to genetic divergence in the frequency of allelles for the alcohol dehydrogenase enzyme. Similar problems were encountered with adult artificial diets. Modern, less aggressive anti-spoilage compounds and antibiotics may prove useful in this area, as will the experience of mass rearing Medfly. In 1973 the cost of production of 1000 pupae was US$ 1, this was 10 times the cost of production of screwworm. Recent cost estimates are not available.

Caging systems – Mass rearing cages of 100 x 40 x 30 cm can contain 2500 adult flies. These are equipped with funnel cones made of ceresin coated nylon gauze through which eggs are deposited. The eggs can then be flushed with water and collected. Light intensity was found to be very important with 2000 lux being considered satisfactory and 4000 being good.

Sterilization – A range of sterilants have been tested on the olive fly, most of which have been very successful. The chemosterilants Apholate, Metepa, Tepa and Hempa[12] all proved effective, but were never employed commercially due to the toxicity of these substances.

Fast neutorns were tested at two doses: 15 Gy induced 0.95 percent sterility in males and 30 Gy was almost totally effective. However, Gamma-ray irradiation was the method established for use with artificially reared flies. Further studies established that 120 Gy of cobalt-60 (^{60}Co) on advanced pupae induced total and permanent sterility in both sexes. A dose of 80 Gy^{60}Co applied to pupae one day before emergence was similarly successful. Neither dose affected mating ability or competitiveness, however, early adult irradiation was found to improve sexual competitiveness strikingly in males. Sterilization using irradiation is most appropriate for current programmes.

Quality control and adult behaviour – Ensuring that artificially reared flies do not diverge significantly from their wild counterparts in their abilities and behaviour after release is an important requisite of a successful SIT programme. Early artificial rearing methods were found to lead to reduced **visual sensitivity**, reduced **dispersal ability** and slower **emergence** from the puparium. This latter leads pupal released flies to be more exposed to predation than their wild counterparts. The photophase regime of the artificial rearing environment also led to differences in the **mating times** of released insects. Mating occurs in the four hours before dark in wild insects and only two hours before dark in lab-reared insects. This has the effect of wild flies being more likely to mate with other wild flies than with sterile released individuals. Both the artificial diets and the density of caged rearings may contribute to these effects and developments in these areas will help minimize differences in quality and behaviour.

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[12] For chemical composition and toxicity information for these insect chemosterilants, see Web site http://www.hclrss.demon.co.uk/class_chemosterilants.html (Wood 2002).

Early field trials – Three field trials of SIT have been carried out in Greece. The first, in 1966, used the chemosterilant Apholate applied to wild flies via baited feeding stations. This led to a substantial reduction in female fertility and fecundity. The second, using irradiated lab reared flies took place on a state prison farm in the mid 1970s. A weekly release rate of 250 flies (both sexes) per tree over a four-month period succeeded in delaying high levels of infestation for a month. The third trial was based on an island 2 km from the central Greek mainland and used a weekly release rate of 1000 sterile flies per tree. In this third test the control areas were treated with aerial sprays of organophosphates. Even with this treatment, the level of infestation under SIT was low compared to the controls until late in the season (end October) when the infestation level of the SIT test area rose to similar levels to the controls.

These early efforts in research and field trials with olive fly in Greece have provided substantial information to use as a basis for future work. The FAO/IAEA Laboratory in Seibersdorf, Austria, recently began its own research in olive fly using a newly established colony started from a Greek laboratory population (IAEA 2003*l*). The IAEA research, carried out in collaboration with researchers from Greece and Italy under EU funding, has focused on two main constraints in the development of SIT for the olive fly, namely expensive larval diets and the lack of a genetic sexing strain (IAEA 2003*l*). In addition, using the Californian laboratory population, the FAO/IAEA Laboratory began strain compatibility studies between olive flies from different origins (IAEA 2005c).

The development of an olive fly lure that would be both cost-effective and specific to the olive fly has proven challenging. Research on improved attractants has compared conventional food lures, such as Ammonium Sulphate (AS) 2% and Spiroketal, against alternatives, i.e. conventional Nulure and the synthetic Ammonium Bicarbonate (AB) and Ammonium Acetate (AA). The McPhail trap with Nulure proved superior (IAEA 2002b). Further tests included more research on potential lures from natural habitats of the pest (IAEA 2004h and 2005a).

California as a market for SIT

While olive fly is a serious pest in many countries, at the time of the original Model Business Plan, the USA appeared to be an important case study for possible demand of sterile olive fly, if the remaining limitations to SIT against this pest were resolved. California has a successful history of using SIT for eradication and more recently prevention of Medfly infestation. Other primary pests of olive are the olive beetle, *Phloeotribus scarbaeoides*, the olive scale, *Saissetia olea*, the olive moth, *Prays oleae*, and other phytophagous moths e.g. *Palpita unionalis* and *Euzophera pinguis*. Prior to 1999 US $100 million were spent annually by growers in California combating these pests. IPM programmes are in place for these pests in California and there are substantial worries that increase in pesticide use to combat the olive fly will adversely affect these other IPM programmes.

Although the area of olive crop harvested in California remained static at around 28 000 acres through the 1960s and 1970s, it had increased gradually in the 1980s and 90s (Table 4.4) when it peaked at 35 300 acres. While this represents only approximately 2.3 percent of world olive production (FAOStat 2001), olives were becoming an important niche crop in some production areas.

Table 4.4 Californian olive crop acreage, production and value, 1990-1999 (CDFA 2000)

Year	**Area** (Acres)	**Yield** (mt/acre)	**Production** 1000 mt	**Value** US $/mt	**Total value** US $1000
1990	30 400	4.33	131.5	423	55 663
1991	29 700	2.19	65	559	36 306
1992	30 100	5.48	165	549	90 561
1993	30 100	4.05	122	467	56 991
1994	32 000	2.63	84	464	38 994
1995	33 700	2.30	77.5	646	50 069
1996	33 700	4.93	166	617	102 364
1997	35 300	2.95	104	642	66 801
1998	35 300	2.55	90	459	41 331
1999	35 300	4.11	145	452	65 564

Historically, the majority of the Californian olive crop is destined for fruit production (Tables 4.5 and 4.6), and are particularly vulnerable to fruit fly damage.

Table 4.5 Californian olive utilised production and average grower return 1990-1998 (CDFA 2000)

	Fresh Market		**Canned**		**Oil**		**Frozen**		**Dried**	
Year	Quantity mt	Value $/mt	Quantity Mt	Value $/mt	Quantity mt	Value $/mt	Quantity mt	Value $/mt	Quantity mt	Value $/mt
1990	500	500	88 000	553	5 000	10.90	22 000	295	16 000	13.90
1991	500	500	53 700	631	1 800	10.30	7 300	291	1 700	23.90
1992	500	500	121 000	676	5 700	10.50	31 500	266	6 300	10.50
1993	500	500	93 000	558	5 300	11.00	19 700	235	3 500	37.20
1994	500	500	66 500	551	4 400	11.00	8 400	234	4 200	14.00
1995	500	500	58 500	779	4 000	11.00	9 300	443	5 200	16.00
1996	500	500	123 000	745	7 000	11.00	29 000	355	6 500	11.00
1997	500	500	82 200	760	3 600	11.00	10 200	386	7 500	11.00
1998	500	500	64 200	590	4 100	11.00	12 800	240	8 400	11.00

In California the olive fly was first noted in 1998 in west Los Angeles. Subsequent delimitation trapping efforts found substantial infestation in surrounding coastal and inland counties. In the following years the olive fly has increased its range and abundance dramatically in both commercial crops and within urban areas where olive trees are used as evergreen ornamentals. The impact was significant. In 1992, there were 1317 farms in California registered as having an olive crop (USDA 2001). Four years after the introduction of the olive fly, only 224 commercial olive producers were registered in California. The majority of these belong to the California Olive Oil Council (COOC), which is setting standards for certification, crop improvement and aims to reduce dependence on imported olive oil. The Olive Committee is an alternative organization and there is substantial overlap in membership. In May 2000, a proposed USDA Olive Oil Promotion, Research and Information Order was suspended due to non-agreement among the various segments of the industry (COOC 2001). There was a lack of consensus over various issues, including olive fly control.

Table 4.6 Percent destination total market value of Californian olive crop 1990-1998 (CDFA 2000)

	Fresh Market		Canned		Oil		Frozen		Dried	
Year	% of crop	Total value $1000	% of crop	Total value $1000	% of crop	Total value $1000	% of crop	Total value $1000	% of crop	Total value $1000
1990	0.38	250	66.92	48 664	3.80	55	16.73	6 490	12.17	222
1991	0.77	250	82.62	33 885	2.77	19	11.23	2 124	2.62	41
1992	0.30	250	73.33	81 796	3.45	60	19.09	8 379	3.82	66
1993	0.41	250	76.23	51 894	4.34	58	16.15	4 630	2.87	130
1994	0.60	250	79.17	36 642	5.24	48	10.00	1 966	5.00	59
1995	0.65	250	75.48	45 572	5.16	44	12.00	4 120	6.71	83
1996	0.30	250	74.10	91 635	4.22	77	17.47	10 295	3.92	72
1997	0.48	250	79.04	62 472	3.46	40	9.81	3 937	7.21	83
1998	0.56	250	71.33	37 878	4.56	45	14.22	3 072	9.33	92

Anticipated source of payment for SIT for this pest
The Olive Committee invested US $50 000 in the creation of a fly rearing and sterilization programme to investigate rearing methods in the face of problems encountered by olive fly SIT work in Greece (sterile female and male mating, oviposition scars by sterile egg laying, etc). In June 2001, at the request of Congressman Doug Ose, the US House of Representatives passed an Agricultural Appropriations Bill directing US $300 000 to olive fly research with a view to the eradication of this pest (COOC 2001).

Already at that time, State and Federal agencies had concluded that eradication of the fly from California was not possible and the priorities for this research funding should be the location and import of bio-control agents and the development of an IPM programme (Russell 2000). Trapping efforts were discontinued in many Californian counties as the olive fly continues to expand its range. Recommendations for control were developed for the conditions of California. These included use of three commercial products: Spinosad (Insecticide product; Dow Agrochemicals, USA), Spiroketal (male pheromone product; AgriSense, UK) and Eco-Trap from Vioryl S.A., of Greece (Zervas 1982). The insecticides have been used in combination with baits (protein baits). Eco-Trap combines the insecticide Deltamethrine and Ammonium Bicarbonate and Spiroketal attractants at source.

Conclusions about the future of SIT for olive fly
Olive oil and olive fruit have gained a prominence as part of an increasing worldwide interest in Mediterranean food and its health benefits. A substantial portion of this market is environmentally aware/sensitive and opposed to the use of pesticides in food production. The use of techniques that potentially result in the product being labelled ‘organic’ will allow premium prices to be commanded.

The distribution of olive fly is very extensive and damage levels can be very high. Other available options for suppression or eradication of this fruit fly pest all have some disadvantages. Besides the use of insecticidal treatments, traditional pruning methods used in the Mediterranean and North Africa encourage light and air penetration to the canopy and reduce habitat suitability for the olive fly. This entails high labour costs as trees require skilled biennial pruning. Thorough removal of fruit from trees and ground can minimize over-wintering, this must be accompanied by fruit harvesting on urban or amenity trees.

In California initial investigations into the experience of SIT in Europe were made and considerable sums of money were committed to this programme (see above). The trials of SIT against the olive fly in Greece showed better protection of the crop when compared to controls. However, the rapid spread of olive fly in California is more likely to be met with the abandonment of the premium quality market by many part-time or smaller growers. The organized commercial growers appeared interested in applying SIT, but this would only have been possible if sterile olive flies became available. The current atmosphere for the US industry is to learn to live with the pest, employing IPM controls without pursuing research to develop SIT.

On the global scale, the outlook for olive fly control by SIT would appear optimistic. Modern rearing techniques and diets should facilitate the production of high quality flies and the introduction of automation will substantially reduce the cost. The main problems of the Greek trials were attributed to low quality of flies and to underestimates of dispersal and immigration of flies of neighbouring populations. With the area-wide application envisaged for future use of SIT against olive fly, the second problem will be much reduced.

4.2.4 *Bactrocera* spp. (other than olive fly)

Distribution of *Bactrocera* species

The genus *Bactrocera* has over 400 species with about 40 of these being economically significant pests (White and Elson-Harris 1992). Probably the most damaging of all fruit flies, this genus is considered to be indigenous to Asia, Australia and the Pacific. Among the most economically significant species of this genus are the Oriental fruit fly (*B. dorsalis*), the melon fruit fly (*B. cucurbitae*), the peach fruit fly (*B. zonata*) and the olive fruit fly (*B. olea*), which is discussed in Section 4.2.2 above, although most of the species cause serious damage where they occur.

Among Bactrocera species, only the olive fly is established in Europe. New species of Bactrocera have been identified in continental Africa, as described below. The Oriental fruit fly is widespread throughout much of Southeast Asia, southern China, Taiwan, Thailand, the Philippines, Pacific islands and Hawaii. The melon fruit fly also is established in Hawaii and parts of Africa. Many species that cause serious damage have remained in limited area, such as the Queensland fruit fly (*B. tryoni*), the papaya fruit fly (*B. papayae*) and the guava fruit fly (*B. correcta*). The Malaysian or Solanum fruit fly (*B. latifrons*) is established in Asia and Hawaii. Maps of distribution for several species can be found under A1 quarantine pests on the European and Mediterranean Plant Protection Organisation's (EPPO) website (www.eppo.org).

The peach fruit fly (*B. zonata*) is also found throughout South and Southeast Asia and in many parts of its range occurs together with that of Oriental fruit fly, reducing the potential value of SIT compared to the use of MAT through methyl eugenol baiting, which controls both species. Unfortunately, *B. zonata* has spread to the Arabian Peninsula and Egypt (see below). It is likely to spread into other parts of Africa and Europe if not eradicated in the near future. Pressing the other direction, over the years, *B. dorsalis* has spread eastwards to Hawaii.

The only *Bactrocera* established in the Americas is the carambola fruit fly, *B. carambolae*, which was introduced to Suriname most likely from its sister former Dutch colony, Indonesia, through direct air flights and frequent visitors. The carambola fruit fly was first recorded in Suriname in 1975. The exotic pest was detected in 1989 in French Guiana, in 1993 in Guyana, and in 1996 in city of Oiapoque in Brazil. A regional control programme began on a small scale with technical activities in 1988; a full-scale MAT and protein bait control programme began in late 1996. This regional programme had maintained eradication from Guyana since 1999 and from 80 percent of land areas of Suriname and nearly all of French Guiana from 2000; with only occasional trappings in Brazil. Unfortunately, the programme was not funded past 2002. Therefore full eradication has not been achieved and a renewal of the population is highly possible (van Sauers Muller 2004).

Male Annihilation Technique to control *Bactrocera*

The distinctive feature of many *Bactrocera* species is their excellent response to methyl eugenol-based attractants. Not all species respond, however, as listed in the annexes of the Thematic Plan for Fruit Fly Control using SIT (IAEA 1999a).

An outbreak of the papaya fruit fly, *B. papayae*, was detected near Cairns, Australia, in October 1995. The response to this by the Queensland Department of Primary Industries was to set up an eradication campaign based on methyl eugenol attractant and malathion insecticide. By June 1997, fly numbers were less than 0.001 flies/week and have now been eradicated. All quarantine restrictions were removed in August 1998 (AQIS 2001).

Under the FAO/Australian Centre for International Agricultural Research (ACIAR) supported project, the Pacific Island of Nauru was declared free from Oriental fruit fly and *B. ochrosiae* in late 1999 following area-wide MAT and protein bait application campaigns (IAEA, 2000b).

In the Indian Ocean, several invasions of *B. zonata* to Réunion were eradicated using MAT during the 1990s, but in 2001 *B. zonata* became established on the island so that eradication will be much more challenging. In addition, *B. dorsalis* was eradicated following introduction to Mauritius in 1996 using MAT with methyl eugenol baited wood blocks impregnated with insecticide (Seewooruthun et al. 2000). In Mauritius, *B. zonata* occurs in conjunction with several species of *Ceratitis* fruit flies, several of which overlap in space and time. Eradication of one species could simply allow others to thrive, if kept without control. In those countries, insecticide treatments would have to be used to control other economic species for which SIT is not available. One possible response could be to embark on an integrated fruit fly management approach where a number of control methods including bait sprays, MAT, biocontrol and SIT could be integrated and used against the main economic species. In the future, any effort to reduce the quarantine threat to South Africa by eradicating *B. zonata* from the Indian Ocean islands could use SIT.

The effectiveness of methyl eugenol as an attractant and its commercial availability will remain critical to the control of this genus. Some species, however are already proving to be immune to the standard attractants for Bactrocera, greatly impairing the chance for MAT. Such is the case of *B. latifrons*, which has recently invaded East Africa from its native Asian range (IAEA 2007c).

Use of SIT against *Bactrocera* species

The MAT approach does not necessarily preclude the use of SIT, however. Japan achieved eradication of the Oriental fruit fly in 1986, after an 18-year program of eradication combining insecticide-impregnated fiberblocks or cotton containing the powerful male attractant methyl eugenol, in conjunction with SIT. The Queensland fruit fly (*B. tryoni*) was successfully eradicated from Western Australian 1991 using sterile fruit fly produced locally (Sproul 2001; also see Section 5.1.2).

The SIT also has received attention in regard to control of other serious pests from the *Bactrocera* genus. At present, genetic, cytogenetic and molecular information on *Anastrepha* species in Latin America and *Bactrocera* species in Southeast Asia lags considerably behind that of Medfly. Because of this, sexing systems in these fruit flies still are being developed. The first *Bactrocera* species with sexing strain for field use is the Oriental fruit fly, based on research by USDA in Hawaii where it is being used in field trials.

Eradication of the melon fly from Japan using SIT
A successful large scale SIT programme against a *Bactrocera* species is the melon fly (*B. cucurbitae*) eradication programme in Okinawa, Japan. The eradication project included large scale area-wide operations over the infested islands starting in the Miyako Islands in 1984 proceeding to the Okinawa Islands in 1986 and finally the Yaeyama Islands in 1990. The field operations included an initial bait spray suppression campaign followed by massive releases of sterile flies to eliminate the population. Ground and helicopter based aerial release of sterile melon flies using paper bags and ground release using hanging bags was carried out on a weekly basis. After eradication was achieved, sterile fly release was continued in every island for at least one year as a preventive measure to avoid reinfestations. An area-wide trapping network based on modified Steiner traps baited with Cuelure and the insecticide Naled was systematically operated to measure the population suppression and eradication effects of the control methods used and to monitor the abundance and distribution of the release sterile flies. In this effort, the public information campaign was key to gaining the support of the general public who in many occasions actively contributed to the activities of the programme (Research Institute for Subtropics 2002).

As Okinawa Prefecture is located in the southern end of Japan and is close to Southeast Asian countries where the melon fly is established, the programme operates a regular detection and quarantine preventive network against re-introduction of the pest.

Eradication of the melon fly from Japan was achieved in October 1993, after 10 years of intensive SIT operations protecting the countries horticulture industry. Eradication of the melon fly using SIT constituted the first success story of melon fly eradication in island communities.

The total programme cost during the eradication period (10 years) amounted to US $172 million. The programme obtained its breakeven point in 1996 after six years of accruing benefits from the eradication. From 1997 to 2000, the total programme costs have been estimated in US $75 million compared to revenues for US $407 million from major host products that were produced and shipped during that period as a result of melon fly eradication. The total accumulated revenues divided by the total accumulated costs during this time period results in the benefit to cost ratio of 5.4 to 1 (Research Institute for Subtropics 2002).

From the point of view of a public investment project in Japan, it is considered as a remarkable achievement that the programme was already generating positive net-benefits after only six years of the eradication (Research Institute for Subtropics 2002).

Control of Oriental and Guava fruit flies using SIT in Thailand
Two species of fruit fly, *Bactrocera dorsalis* and *B. correcta*, cause significant damage to the Thai mango industry (Enkerlin 2001b). The Oriental fruit fly, *B. dorsalis*, has been the subject of pilot suppression programmes using an integrated SIT based control programme in the Paktor district of Ratchaburi province since 1992. The current programme has been successful

in reducing the level of damage from over 50 percent losses where low input conventional control was previously used, down to about an average of less 5 percent with the use of an integrated approach including SIT. The use of SIT has provided comparative market advantages to the mango growers of this district who are exporting 60 percent of the production to countries that discriminate for quality, including absence of insecticide residues. Due to the differential price obtained in the export market the mango growers have doubled the gross revenues (Figure 4.6). This success has encouraged other mango growers who are actively requesting support from the government to embark on a SIT programme (Sutantawong et al. 2002).

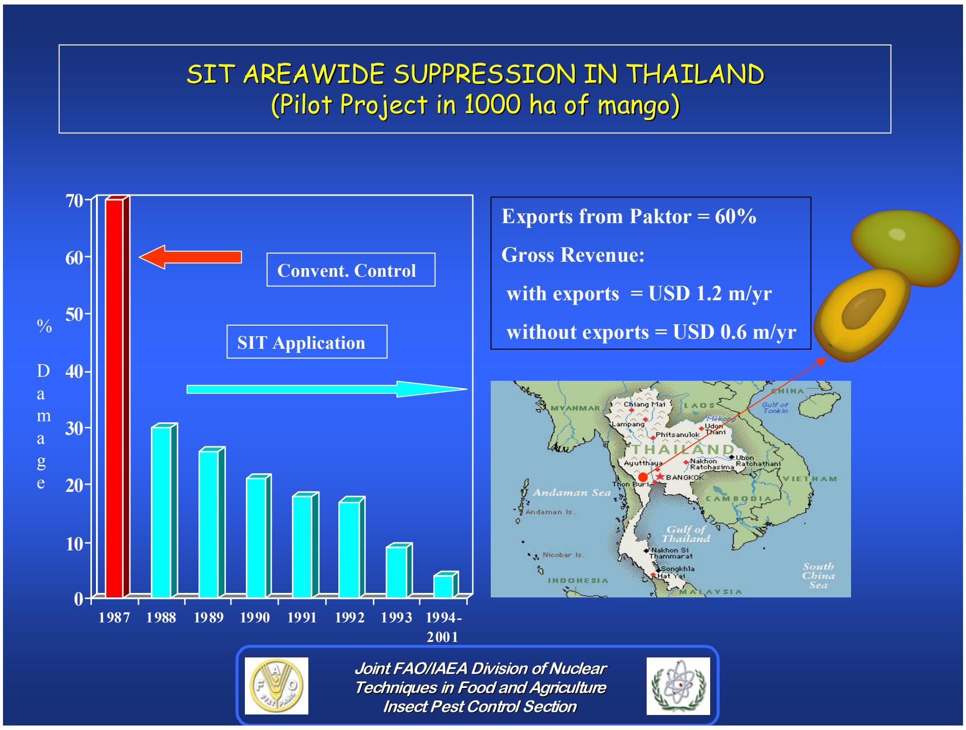

FIG. 4.6. Impact of SIT application for control of the Oriental fruit fly (B. dorsalis) in a commercial mango production area located in the District of Paktor in Thailand.
(Source: Sutantawong et al. 2002)

Thus in 2002 the Department of Agricultural Extension (DOAE) launched a pilot project, similar to the Paktor programme, to control *B. dorsalis* and *B. correcta* (Guava fruit fly), in the Province of Phichit, covering an area of about 35 square kilometers. This project involves mass rearing and sterilization of *B. dorsalis* and *B. correcta* at the facility of the Institute of Irradiation for Agricultural Development, operated by the DOAE. It also entails field releases of sterile flies complemented by other control methods, such as bait treatment, MAT and a trapping network of methyl eugenol based traps.

The project is a joint venture between the DOAE and its provincial office, contributing know-how and sterile flies, and mango producers, carrying out field operations. The use of SIT under an integrated approach in the Phichit Province was successful. In the first year, it resulted in the reduction of mango crop damage from the historical average of 30 per cent yearly to 19 per cent of the harvest (IAEA 2003k).

A recent economic assessment prepared by Knight (2002) shows that SIT for Oriental fruit fly control is economically viable for most of the Provinces in Thailand that produce mango. For those Provinces where SIT is economically feasible the benefit to cost ratio ranges from 1.3 to 3.1. There would appear to be significant gains to be made from the use of SIT suppression in many mango-growing areas of Thailand. However, one problem that requires further attention is the additional presence of *B. correcta* in some areas, which may prevent the full benefits of *B. dorsalis* control from being achieved. Indeed, in some areas *B. correcta* is the dominant species and the SIT would need to be targeted at both species.

Fortunately, the mass rearing and sterlization techniques for *B. correcta* are available in Thailand. If the government of Thailand decides to launch a national fruit fly SIT programme, more work will be required to assess the level of damage of both species in the different Provinces where mango is commercially grown. This will be essential for assessing the size and production capabilities of the mass rearing facility based on the required numbers of sterile flies of both species. This will also have an effect on the benefits and costs of any such future programme.

The fruit fly control projects in Thailand require an overall production of 40 million sterile flies per week whereas currently, this amounts to 30 million flies per week, that is, 20 million *B. dorsalis* and 10 million *B. correcta*. Thus, the sterile fly production facility has embarked on building up its *B. correcta* colony to accommodate the production of 15 to 20 million pupae per week. The SIT based projects in Thailand also require the production of high quality sterile flies. It should be noted that the effective irradiation dose for *B. dorsalis* and *B. correcta* has been set at 90 Gy and 80 Gy, respectively (IAEA 2003k).

Opportunities for SIT against *B. zonata*
The peach fruit fly has always been a serious pest. It has been estimated that in Egypt this one species causes an estimated US $177 million of damage each year. The pest has been reported to be seriously damaging to mango, guava, apricots and peaches crops. Its most recent distribution is shown in Figure 4.7, although additional spread is anticipated and may have occurred and simply not yet been detected (EPPO 2002). As noted above, the peach fruit fly has been controlled and localized populations even eradicated using MAT. More wide spread populations are difficult to eradicate entirely with this technology, however, and an integrated approach that includes SIT should be carefully considered given the importance of this species and its recent spread.

With the expansion of its range, the control of B. zonata is of increasing concern. Following its introduction and spread in Egypt, and the several detections which occurred in some countries of the Near East region, the Egyptian Government has been joined with FAO and IAEA in assessing the incidence and severity of peach fruit fly, *B. zonata* (IAEA 2001h). At the request of Egyptian Ministries of Agriculture and Electricity and Energy, a pre-project mission was carried out in preparation for the IAEA Technical Co-operation Project (EGY5025) on fruit flies "Area-wide fruit fly control in Eastern Egypt". The population levels of B. zonata are on the increase and in some areas the species even displaces Medfly. The peach fruit fly is a serious threat to Egypt's mango, stone fruit and citrus production and export and a serious threat to Egypt's trade partners and neighbouring countries. Some disagreement exists over when and where B. zonata was introduced and established in Egypt, but all appreciate the need to stop this pest becoming established in Mediterranean countries (IAEA 2001h). In deed, the European Food Safety Authority (EFSA) recently reviewed and reconfirmed the importance of regulatory controls to prevent B. zonata from becoming established within the European Union (EFSA 2007).

FIG. 4.7 Known distribution of Bactrocera zonata.
(Original map updated based on the Report of the EPPO Workshop on *Bactrocera zonata*, Paris, UNESCO, 2002-03-05)

In connection with the identification in Egypt of the peach fruit fly, Israel, Jordan and the Territories Under the Jurisdiction of the Palestinian Authority have strengthen their quarantine inspection service and their detection trapping network to assess the presence/absence of the new pest (IAEA 2001i). Israel has eradicated few incursions using MAT, thanks to early detection of the outbreaks.

The establishment of peach fruit fly in Egypt has caused alarm not only in that region, but also in Europe where it could easily spread. The Comité de Liaison de l'Agrumiculture Méditerranéenne (CLAM) members were alerted to the presence of the peach fruit fly in Egypt at a peach fruit fly workshop held in Valencia, Spain (IAEA 2001h). A peach fruit fly identification guide was prepared to support detection work in the newly threatened regions.

The European Plant Protection Organization (EPPO) hosted a workshop on this pest in early 2002 to assess the risk of its introduction to Europe (EPPO 2002). Based on the conclusions of the workshop, the EPPO Working Party on Phytosanitary Regulations recommended ranking *B. zonata* as A1 Quarantine Pest and the EPPO Council added the peach fruit fly on the A1 list of quarantine pests for the EPPO Member States.

A cost benefit analysis of eradication of the peach fruit fly from Egypt conducted in 1999 showed that other schemes such as MAT and bait treatment are more financially viable than SIT in its present state of supply. However, the report recommends SIT as a method of control due to its suppression and eradication capabilities, which could be used in Egypt in areas of high damage such as the Faiyoum and the Delta. The overall recommendation was to employ all three methods of control due to the severity of the problem and the potential consequences if the peach fruit fly is left unheeded (Joomaye et al. 1999). It now remains to develop production capacity of sufficient sterile peach fruit fly to support SIT in these newly infested areas.

Emerging species of concern throughout Africa
Particularly in context of the experience with *B. zonata*, a newly described species of Bactrocera. *B. invadens* (Drew 2005), is causing great concern throughout Africa and even into the Middle East and Europe (EPPO 2005). Apparently originating in Sri Lanka, this species was identified from detections in Central Africa in 2003 and has since spread very rapidly to more than a dozen Central and East African countries. Primarily a pest of citrus, mango and other tropical fruits, this species is still relatively unknown and may have been present for some time before detection. Initial work on mass rearing is underway in the interest of pursuing SIT. An initiative to register appropriate pesticides for use on mango is also on going (PIP 2007), with the lucrative mango export trade from West Africa to the European market in mind.

4.2.5 Other fruit flies of economic importance

There are many other fruit fly species of economic importance that may merit control. Species of great importance in a small geographic area may not have the research background of those discussed above.

In general, the genus of *Rhagoletis* Loew is a more serious pest, in comparison with other fruit fly genuses, in temperate areas because of its tolerance of cold. Many *Rhagoletis* species occur in the subtropics and tropics, however. For example, Foote (1980), cited by Enkerlin et al. (1989), states that 21 species occur in Mexico, the West Indies and throughout most of America. However, only few are considered to be of economic significance. In temperate climates of western USA and Canada, *R. indifference* is of particular concern in cherry production and *R. cerasi* across Europe. The apple maggot (*R. pomonella*) is considered to be a key pest of apple in Eastern United States and it is also present in the northwest Pacific coast. These two species, in particular *R. indifference,* could be ideal candidates for SIT since they have only one generation per year and the host range is very limited. In addition, the reproductive performance of male *Rhagoletis* can be enhanced through protein nutrition in the days following eclosion, as recent studies have suggested (IAEA 2005g). Presently, commercial cherry growers rely on repeated insecticide treatments to keep populations under economic threshold.

4.3 The market for sterile moths

The majority of experience with SIT to control Lepidoptera is with codling moth. Successful efforts using SIT against codling moth and ongoing work with other moths are discussed below. Some discussion of sterile codling moth production appears in Section 5, along with a map of current production facilities.

4.3.1 Codling moth

The codling moth (*Cydia pomonella*) attacks apple, pear, quince and walnut, in particular, causing a high level of economic damage. It is considered one of the key pests of temperate and subtropical fruit production in more than 70 countries (FAO/IAEA 2000b). For example, tens of millions of US$ in damage have been reported in Syria alone for its fruit growing regions (Mumford and Knight, 1996). Similarly, in the provinces Neuquén and Mendoza, in Argentina, the reported crop damage was 10 to 20 per cent, while, in Neuquén, the economic loss reached US$ 26 million in the 2002-2003 season (IAEA 2003n).

Codling moth damages the fruit itself, so that the pest can only be tolerated in very low numbers before drastic measures must be taken as the market value of the crop is decimated. Therefore, eradication is highly desirable as pesticide management schemes are expensive and have a large environmental impact. Insecticide resistance is becoming apparent (especially in America) where more extensive spraying is now needed to reduce the pests' presence. The SIT also may be applied successfully for annual suppression of codling moth, however, as demonstrated in the Canadian programme. Organic markets are potential opportunities with the use of SIT, once the population has been brought down sufficiently to warrant no use of pesticides.

Fortunately, in general, the pome industry's level of organization is very high, with many interactions between growers especially on a national scale. Many grower associations have been set up, for example in Australia the Australian Pome Fruit Improvement Program Ltd, a non-profit organization, was established in 1997 for the benefit of the pome fruit industry. It was set up by pome fruit growers and is supported by levy that is matched with government funds in order to promote research, development and cooperative methods in the region. This is just one example of many associations set up with similar aims. In most countries there are such associations, usually with government affiliations, which vary in their contributions to the industry. As a result, the industry is highly developed with good infrastructure.

In addition, unlike some other sectors of horticulture, the pome industry has welcomed IPM as a principal method of crop protection. In other cases, securing the level of understanding by growers to enable adoption of IPM techniques on farms has proven difficult (Merriman 2000). This level of organization and familiarity with IPM, however, makes the industries impacted by codling moth more likely to participate in funding of and successfully participating in SIT programmes than might be the case for some other industries.

Distribution

Coddling moth is one of the most wide spread pests of fruit production regions. The *Cydia pomonella* was first recorded as a pest in 1635. It is known that early settlers introduced codling moth from Europe to North America more than 200 years ago. It then spread and became the number one pest of apples and pears in North America (OKSIR 2001; Welty 1991) and a serious pest in South American fruit-growing regions.

From Figure 4.8 it is apparent that the codling moth is present in all the continents of the world. Without quarantine and inspection procedures, potential for re-infestation into eradicated or low population areas is high. However, it must also be noted that only a small percentage of the codling moth females migrate over a few 100 m each year (OKSIR, 2001).

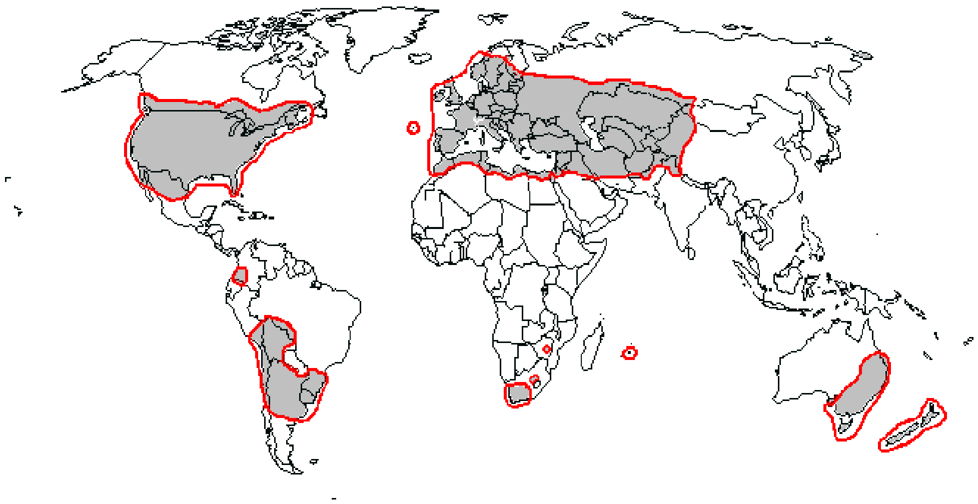

FIG. 4.8 Distribution of the codling moth (Cydia pomonella) in 1997.
(Source: Bajwa and Kogan 1997)

Unrestricted movements of fresh fruits from one country to another in the past allowed this insect to gradually spread to uninfested areas. In Syria, for example, the codling moth was only first reported in the 1950s, however it is very likely that it had established there long before this date (Mumford and Knight 1996). The most common method of transportation from one place to another has been through the movement of infested fruit and fruit containers.

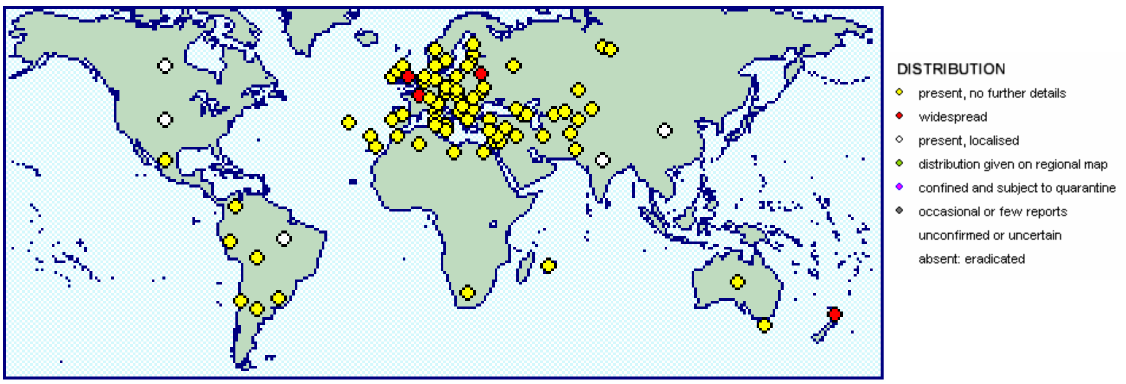

FIG. 4.9 Distribution of the codling moth (Cydia pomonella) in 2006.
(Source: CABI 2006)

Figure 4.8 shows the distribution of the codling moth a decade ago, without removing those areas where control campaigns may have limited populations or including locations of infrequent outbreaks that are eradicated. In the CABI map (2006), there is also the distinction made between localised and widespread populations (Figure 4.9). In the intervening years, additional areas in China have been listed as having established, albeit localised, populations; little other change in distribution is noted, however. This slowing of invasion related to imports and exports can be attributed to the quarantine regulations in place to prevent the pest's entry to uninfested areas, such as Japan. Therefore codling moth control is motivated by potential impact on trade as well as the direct damage.

Description and biology
The codling moth has a different number of generations in a season depending on its geographical location. In more northern territories, (e.g. Russia, Canada and the UK) only one generation will be completed each year, whereas in Israel five generations are not unusual. The decrease in generation time occurs gradually, the more southerly the location.

Rainfall is the most important cause of mortality of the first instar larvae when they were just beneath the epidermis of the fruits. Rainfall and temperature largely affect oviposition in the first generation (as tunnels are flooded). In the second generation, temperature is causal. Overall, it is a common theme that mild winters and hot summers promote codling moth populations.

Development occurs within the fruits and so larvae are adequately protected from desiccation. However if humidity drops below 40 percent, then significant mortality occurs. Prolonged frost may have a desiccating effect. Increased humidity in the spring (of the Northern or Southern Hemispheres) promotes simultaneous pupation in over-wintering caterpillars.

Photoperiod affects diapause induction and expression. Furthermore, it also affects the rate of development of the codling moth. Diapause is dependent upon both environmental and genetic factors. Environmental factors include temperature, photoperiod, food and population densities. Critical photoperiod varies as to the geographical location of the population. The codling moth has a facultative type of diapause but a gradual increase occurs in obligatory diapause from south to the north. This increase in obligatory diapause in the northern populations is advantageous to the species because the growing season is short and the food supply and weather tend to vary more. Temperature and photoperiod both play a role in diapause termination. Photoperiod however is the primary factor (Welty 1991).

Birds are important predators of hibernating larvae that are under loose bark. Parasites can attack eggs and larvae of the developing codling moth. Some worms always escape natural control so chemical controls are usually needed in addition because of consumer demand for blemish-free fruit.

Pest population level and damage
Codling moth has an enormous potential for damage among its target hosts. It invokes two types of damage to the fruit, stings – entries where the larvae bore into the flesh of the fruit a short distance before dying – and deep entries, which cause much more extensive damage as the larvae bury in to the core and feed in the seed cavity (see Figure 4.10). The larvae can enter the fruit from pretty much anywhere on the surface; the characteristic marks of larva infestation are one or more holes plugged with frass on the fruit's surface.

Codling moth can be effectively controlled with properly timed treatments. If left unchecked, the resultant damage to crops from infestation can be 80-100 percent. Levels of damage may be more severe in warmer climates where the moth undergoes many more generations per year (Welty 1991).

Current control methods
Some control may be achieved through orchard sanitation and hand labour. Fallen fruits should be removed as soon as possible, as these often harbour many codling moth larvae. Corrugated cardboard strips attached (two to four inches wide) to the tree trunk and scaffold branches in June and August (Northern Hemisphere) provide a site for the larvae to make cocoons. After the cocoons have formed, the cardboard can be removed and the cocoons

destroyed. Before the bands are attached, the bark should be scraped to remove loose pieces that would prevent a tight fit by the strips.

FIG. 4.10 Picture of deep entry damage by codling moth larva (University of California).

Repeated applications of insecticide every 10 to 14 days are usually needed from petal-fall to near harvest. Sprays are most effective when applied just before newly hatched larvae attempt to enter the apples. If a pheromone trap is used to monitor codling moth, the best time to spray is two weeks after the first moth catch or one week after a peak catch (Welty 1991).

The pesticides traditionally used in control of codling moth included Isomate-C, CheckMate CM, Disrupt CM (mating disruptants), tebufenozide (kills larvae mainly used in areas where populations of codling moth is relatively low), azinphosmethyl, carbaryl, phosmet and narrow range oil (mildly effective). The use of these pesticides have been extensively studied, however at present the emphasis is on development and application of IPM schemes that are best suited to particular regions using existing methods of control.

Recent research on the efficacy of mating disruption treatments revealed that sprayable pheromone formulations alone failed to provide sufficient codling moth control. These need to be supplemented with insecticide spraying, particularly in orchards with high codling moth populations (IAEA 2006f), or in areas with steep slopes or dispersed orchards.

Excepting the mating disruptants, the pesticides used impact more species than just the codling moth. Many of the pesticides used are broad-spectrum synthetic insecticides, which kill many beetles and bugs. For example phosmet (Imidan) is an organophosphate pesticide, which can be toxic to beneficial insects such as codling moth parasites as well as the moth itself. The other main example of a broad-spectrum insecticide used in the past is carbaryl (Sevin) (Welty 1991). In addition, intensive use of insecticides resulted in resistance and cross-resistance of moths to these products. Research in the Czech Republic, carried out in 2004-2005, found resistance to organophosphates and insect growth regulators in the local codling moth population, thus emphasising the need for alternative measures to control codling moth (IAEA 2006f).

As a general rule, the restrictions on importing and exporting fruits are tight, especially between developed countries. In most fruit producing countries there is an IPM scheme to combat codling moth (FAO/IAEA 2000b). Hence any imports and exports that could potentially act as a new source for the pest's reinvasion are curbed immediately.

Use of SIT in control of codling moth

Previous research has found that Lepidoptera are more resistant to radiation so that the level required causes some decline in quality of the sterile pest. The solution to this has been to explore the concept of SIT with the sterility factor arising in the field in the first generation, rather than the released insects being fully sterile. Inherited sterility, referred to as F_1 for the first generation, has proven successful in the field. The only limitation is the regulators' ability to recognize the sterile insects when captured in monitoring traps and the producers' acceptance of a slightly more complicated concept for pest control.

Laboratory techniques of mass production and appropriate artificial diets are well established. Yet, local populations must still be tested for appropriate sterilization treatments. A dose of 150 Gy induces total sterility in female moths sourced in Syria. Ukrainian sourced populations required a dose of 300 Gy. This indicates that there is a degree of genetic differentiation between regional populations. A dose of 350 Gy did not affect male longevity or mating competitiveness, but did reduce the number of their matings.

The only large scale production of sterile codling moth is in the British Columbia plant, which has a capacity for 14 million male and female per week (see IAEA directory of facilities). The irradiation dose used in this facility is 150 Gy. This successful example of colding moth control, introduced in 1994, has resulted in most growers within the SIT program area no longer having to spray against the codling moth. This means that in some of the areas, where management of other insect pests can be done via biological control methods, production can be organic (OKSIR 2001).

In addition to SIT, the British Columbia programme utilizes mating disruption, some insecticides and tree-banding to destroy mature larvae in an IPM approach (OKSIR 2001). With several years of experience, the biggest challenge to this programme now is the poor return for fruit in the regional and international market. A discussion of financing of this programme appears in Section 3 and a photo of the facility appears in Section 5.

Effective expansion of the SIT as a component of area-wide IPM programmes against codling moth elsewhere requires further research and field evaluation. A four-year Coordinated Research Project (CPR), introduced in 2002, has sought to further develop SIT and inherited sterility (IS) in control of this pest through activities concentrating on various aspects of rearing and implementation (IAEA 2002d).

Expansion of SIT against codling moth

The area in fruit crops affected by codling moth is huge. Total world production in apples is over 63 million mt and pears over 19 mt (FAOStat 2006). Some countries specifically interested in SIT against codling moth are South Africa, Syria, Argentina and Chile (FAO/IAEA 2000b). European countries are facing increased pesticide resistance in codling moth populations and have expressed interest in applying SIT against codling moth and even in constructing the facility to supply the sterile moth (e.g. Portugal, A. Mexia, pers comm 2000).

Argentina has taken steps toward the area-wide application of SIT against codling moth, with the support of the IAEA and the Canadian Okanagan-Kootenay Sterile Insect Release facility (IAEA 2003n). Codling moth production is expected to reach 200 000 moths per week by mid-2006. In addition, the first trial release of moths irradiated at 150 Gy took place in 2006, which will be evaluated by trapping (pheromone lures), by fruit damage assessment and by evaluation of over-flooding ratios and induced sterility (IAEA 2006b).

Research in Canada has included developing a cost-effective and efficient pupal collection system to facilitate the long-distance shipment of large quantities of codling moth pupae (IAEA 2004g). In 2004, a pre- and post-transit quality assessment of four packages of sterile moths and pupae, shipped from the Canadian rearing facility to Stellenbosch, South Africa via commercial freight routes, revealed that long-distance transport did not affect the quality of moths. These successful trials led to the initiation of four additional consignments of increased quantity of moths and pupae, in August 2005. The moths will be used in a season-long field study in a selected area in South Africa (IAEA 2006b). Early small-cage and field experiments conducted in Stellenbosch, South Africa, indicated a complete absence of mating barriers between moths from the Canadian rearing facility, shipped as adults and pupae to South Africa, and the South African strain. They also showed that Canadian and South African females did not differ in their ability to attract both Canadian and South African males over a broad range of environmental differences (IAEA 2004g; IAEA 2005d; IAEA 2006d).

Additional field cage tests were carried out at the Entomology Unit, in Seibersdorf, using diapausing larvae of wild and laboratory populations from various countries (Argentina, Armenia, Canada, Chile, New Zealand, Switzerland and the Syrian Arab Republic). In many cases, the variation was inconsequential (IAEA 2006b and 2006d), which would allow the use of sterile codling moth produced in other locations and imported for field release.

Progress has also been made in developing genetic sexing strains for codling moth using genetic and molecular tools as well as chromosomal translocation and transgenesis, as recommended by the IAEA Group of Consultants in May 2003 (IAEA 2003c; 2004g; 2006b). Success with temperature lethal genes could be pursued for further improvements in the species adaptability to SIT.

Complementary approaches

A USDA/ARS area-wide control programme for codling moth in the states of Washington, Oregon and California was based on mating disruption using sex pheromones. Applications of organophosphate insecticide was reduced from three to one or even no applications annually. The programme was increased to 21 000 acres and 466 growers in 1999. This was a new level of cooperation for area-wide control and required awareness of the efficacy of the approach when producers were accustomed to insecticides. Federal legislation encouraged the reduction of pesticide applications (FAO/IAEA 2000b).

Mating disruption has been particularly successful in pear orchards. This approach was applied to other sites in Washington state so that by 1999 there were 60 000 acres under this regime. As with SIT, mating disruption is more effective when populations are low. Therefore costs in the USDA project were reduced from around US$135/acre to US$105/acre in just four years; this final level was below cost of the traditional insecticide regime. Some secondary pests became more problematic without the pesticide use, so that biocontrol agents were under review to balance those emerging pests. Currently fruit production in much of the world has very low economic margin, so that costs of these alternatives is critical to their acceptance (FAO/IAEA 2000b).

A small part of the USDA project site located near the border with Canada was under both mating disruption and SIT regimes. In this area, no pesticide was required and extremely good control of codling moth was achieved (FAO/IAEA 2000b). These types of complementary approaches are important components for future IPM against codling moth.

In Argentina, some growers use pheromone traps for population monitoring and mating disruption as well as traditional control measures. These control methods, however, are not cost-effective. Growers spend from US$ 450 to 850 per hectare annually with a residual damage ranging from 3 to 20 per cent. In addition, the IPM national programme for codling moth mating disruption, introduced by El Servicio National de Sanidad y Calidad Agroalimentaria (SENASA) in pear and apple commercial production areas, has been rather unsuccessful. The industry and the provincial authorities are very interested in the use of an area-wide IPM approach based on SIT, particularly because of the successful control of the moth in Canada and because of the infrastructure and expertise available in Argentina for medfly control with SIT (IAEA 2003n).

Brazil has an area-wide scheme to control and eventually eradicate codling moth, from the four affected municipalities, Vacaria, Bom Jesus, Caxias do Sul and Lages. This scheme involves a trapping survey to delimit the spread of codling moth and to monitor the population density. It also includes the replacement of untreated host trees with non-host trees and the use of attract-and-kill traps. These measures resulted in a significant reduction in the codling moth population, particularly in the urban areas. In addition, a feasibility study assessing the potential application of an integrated programme, based on SIT, emphasised the benefits from the elimination of the codling moth in urban areas in the above municipalities (IAEA 2006b).

Experimental releases of codling moth egg parasitoids, *Trichogramma nerudai* and *T. cacoeciae*, demonstrated good ‘finding capacity’ (ranging from 4 to 58 per cent) of these parasitoids. They also showed regular levels (ranging from 2 to 31 per cent) of ‘parasitism efficiency’ and a ‘field persistence activity’ of one week. Finally, these releases revealed that both parasitoids could infest both sterile and partially sterile coddling moth eggs. Hymenopterous egg parasitoids (*Trichogramma* spp) have been noted to prefer fertile eggs and their use in the field concurrent with SIT is likely to prove highly efficient.

Further evaluations of the feasibility of using parasitoids, in combination with SIT, will be conducted under laboratory and semi-field conditions. In addition, research will explore the impact of host plant removal, SIT and other relevant technologies on the bionomics and the spreading of codling moth from infested areas into uninfested areas. Finally, research will examine the effects of codling moth natural enemies and of refugia on population dynamics and re-infestation (IAEA 2004g).

The use of SIT has been shown to allow development of biocontrol of secondary pests as well, further reducing the need for pesticides.

4.3.2 The market for sterile date moth

The date moth (*Ectomeylois ceratoniae*) also know as carob moth or by other common names, as well as by other scientific names (see Annex 5), is a wide-spread pest of date palms, several types of nuts, citrus, pomegranates and other fruits. Damage varies according to the host, its variety, the cultural and climatic conditions, but in many situations there is a need for alternative, more effective control that avoids use of pesticides.

Under sponsorship by IAEA, the *Institute National Agronomique de Tunisie* (INAT) has been working for some years to improve the mass-production of date moth. This project uses a local strain that has been produced in the laboratory since 2000. Approximately 1.5 million moths per week are produced (male and female). The dose of radiation used for sterilization is 400-600 Gy, although studies continue to determine the optimal rate. Larvae are marked with Calco-Red dye, added to the diet and remaining in the internal organs of adult moths. This method has solved the previously experienced problem of larval mortality, attributed to colorant.

Recent research has focused on rearing date moth in diapause and on evaluating the competitiveness of diapaused versus normally reared moths through field trials. Diapaused moths rearing will facilitate releases in early spring, when the natural moth population is low. Following field studies to examine the behaviour, competitiveness, longevity and the dispersal characteristics of released sterile moths, INAT has started a field pilot trial to evaluate the success of SIT against date moths under operational conditions.

The SIT approach is very suitable for southern Tunisia, where damage by date moth is extremely high (i.e., infestation in pomegranates is 90 per cent) and because of the isolated locations of most date palm plantations. Complementary control methods currently employed include the use of nets and plastic bags over dates, sanitation measures in plantations (i.e., removal of fallen fruit and other host trees) applications of *Bacillus thuringiensis* (Bt) and fumigation of harvested dates with methyl bromide (IAEA 2003b). Improvement in the attractants used for monitoring the pest will increase the chances for successful SIT. Research on this issue is also being sponsored by the IAEA. Perhaps within a few years the use of mass reared date moth will be commercially viable, assuming larger production facilities are organized to allow for a more cost-effective production process. There appears to be good promise for the future use of this species for SIT given the range of hosts it attacks, the limitations of the existing control measures and the distribution of the pest.

Further information on the production system for date moth appears in Section 5. The impact of this pest on date palm in various countries with important production is described in the study in Annex 5. Current control measures are also described in that study.

4.3.3 SIT control of Cactus Moth

Prickly pear cacti belong to the genus *Opuntia* (Cactaceae), of which there are around 200 species. In the New World they are distributed from Canada through to South America, but are most abundant in arid areas such as Mexico – which is recognized as the centre of endemism for this genus. In those areas, *Opuntia* is a dominant component of the plant community. They provide food and moisture for herbivores, shade shelter, “nurse plant” and nesting sites for many creatures. To humans, the prickly pear has uses as an edible fruit, livestock forage, in cochineal dye production and in gardening where it is used as an ornamental plant. In addition, the cultivation of *Opuntia cacti* has become increasingly important in some Mediterranean countries, for instance, Italy, Spain (particularly in the Canary Islands), Israel, and Tunisia (IAEA 2003f). Thus *Opuntia* have been purposefully distributed around the world before the potential invasiveness was considered. Unfortunately, in some areas where it is not native it has become a pest as it often out-competes native plants. To tackle the problem, a species of insect *Cactoblastis cactorum* has been used as a non-specific biological control in many schemes to suppress and eradicate the weedy prickly pear. Cactus moth, for instance, proved to be an effective control agent against exotic invasive cacti in Australia and South Africa (IAEA 2002e; IAEA 2006a; Zimmermann et al. 2004).

FIG. 4.11 Early human use of Opuntia.
Source: http://www.jornada.unam.mx/2000/feb00/000204/Images/eco-portada.jpg

According to Mahr (2001), in 1957 *Cactoblastis cactorum* was released on the island of Nevis (West Indies), where cactus was a problem to livestock on overgrazed land. The release was extremely successful and was repeated for Montserrat and Antigua (1960). Subsequently the moth has appeared unintentionally on St. Kitts, the US Virgin Islands and the Dominican Republic. In 1989 the presence of *Cactoblastis cactorum* was first registered in Florida. Some experts have argued that nursery exports from the Dominican Republic, containing infested plants, contributed to the rapid spread of the moth within the Caribbean and to the USA from the 1970s through to 1990s, due to the high incidence of the moth's presence in the Dominican nurseries and the ignorance of its impact at that time (IAEA 2006a). The unintentional introduction to the mainland US poses a huge threat to the indigenous populations of *Opuntia*. How it arrived has remained unclear, but since its first appearance, *Cactoblastis* has spread northwards and westwards and now is causing damage to areas on the coast of Georgia (650 km away) and along the Gulf of Mexico approaching the state of Mississippi.

As there is a continuous distribution of susceptible cactus species from southern Florida to the Gulf coast states into the southern Midwest and Southwest, there is a likelihood that *Cactoblastis* will spread throughout *Opuntia's* natural range. It has been predicted that it will spread through Texas down into Mexico, where the impact will be huge. However, the chances of the cactus moth spread from the Caribbean to Mexico, via nursery trade, tourism and natural dispersal, for instance, are very small due to the low populations throughout the

Caribbean (a result of the decline in host plant numbers) and due to the increased awareness of the moth's threat to Mexico and the USA (IAEA 2006a).

Nevertheless, hurricanes in the region, which are increasing in frequency and intensity, could very well be a source of spread especially from Cuba to Mexico and the USA. In addition, the number of Cubans entering Mexico illegally through the Yucatan Peninsula has increased in the last years from 157 in 2004 to 572 in 2006 and 114 until March 2007 (from El Universal Newspaper March 30, 2007). The moths which could be attracted to boats at night by light can very well survive a relatively short trip from Cuba to Isla Mujeres or mainland Quintana Roo, Mexico. The impact of cactus moth on *Opuntia* species in the Caribbean varies, depending on the size of the plant. Small- and medium-sized species, including species initially targeted for biological control, such as *O.* dillenii and *O. triacantha*, are particularly susceptible to moth damage. In effect, several of these species are regarded as 'threatened' by the International Union for the Conservation of Nature and Natural Resources (IUCN). Larger *Opuntia* species, including some rare *Consolea* species, are sub-optimal hosts. New growth of these species, however, is most vulnerable to cactus moth and can, in turn, cause damage to mature plants (IAEA 2006a).

A pest risk analysis estimated that, in Cuba, at least eleven *Opuntia* species are potential hosts. Official host records include *O. dillenii*, *O. ficus-indica*, *O.* (*Nopalea*) *cochnillifera* and two unidentified taxa. Nonetheless, *O. militaris* and *O. triacantha* are the most endangered species, as their limited distribution on the island suggests (IAEA, 2004*o*).

Host plant testing of *Cactoblastis* has been conducted at the USDA-ARS laboratories in Tifton Georgia and at the University of Tucuman in Northern Argentina. Data indicate that cactus moth can infest, develop and reproduce in some of the *Opuntia* species not normally infested in its native distribution range. This information will be useful to assess the potential total biotic impact of its spread in the Southeast United States and Mexico. Mexican growers already use certain insecticides on *Opuntia* crops as means of pest control and this practice may limit the damage from *Cactoblastis* when it arrives to that region. Pesticide application is not a practical or environmentally sound way to protect the millions of hectares of natural *Opuntia* vegetation that will be affected in the meantime.

In July 2002 the Technical Cooperation Department of IAEA and Joint FAO/IAEA Programme organized a Consultants Group Meeting to encourage interregional coordination in addressing the spread of the cactus moth and to facilitate the preparation of a work plan (FAO/IAEA 2002). The most promising eradication and containment tool is SIT. The proposed programme should initially focus on affected and at risk countries, namely the USA, Mexico, Cuba and other Caribbean countries but also be available to several countries, potentially threatened by cactus moth. However, further research and development is needed to refine control and eradication measures and, thus, to ensure their effectiveness. In addition, national and international initiatives to increase the rather low awareness of the cactus moth threat are required (IAEA 2006a).

The use of sterile insect release technique (SIT) has a major advantage in that it is species specific and environmentally friendly. Therefore it would be suitable for the elimination of the insect from isolated and environmentally sensitive areas as well as from areas of new introductions. SIT would also be useful for measuring the host range and for assessing both the potential geographic distribution of the moth and its natural enemies (IAEA 2002e; Zimmermann et al. 2005). The proper dose of radiation has been established (Carpenter et al. 2001a) and the species is being currently mass reared in artificial diet at the ARS laboratories in Tifton, Georgia. For the past two years moths have been reared, sterilized and released in the Coast of Alabama where a pilot SIT project is being conducted. An effective synthetic cactus moth pheromone has been developed and now being used as part of the surveillance network in the USA and Mexico (Heath et al. 2006; IAEA 2004a; IAEA 2004j). The availability of a monitoring and detection tool is fundamental for the application of SIT technology. At present, cactus moth has been detected in Alabama, near the border with Mississipi, and spreading at an estimated rate of 158 km per year. It is expected to reach Texas by 2007 (IAEA 2004p). The first step would be to contain the pest by means of a barrier of sterile insect releases integrated with other control methods including mechanical control, regulatory control, and public information (Carpenter et al. 2001b).

51.18 Biological Control of a Pest *Cactoblastis* caterpillars consume an *Opuntia* cactus, a pest in Australia.

FIG 4.12 Damage from cactus moth, an effective biocontrol agent.
http://www.micro.utexas.edu/courses/levin/bio304/com&pop/cactoblastis.cat.gif

In July 2004, Mexico's Plant Protection Directorate General and the Joint FAO/IAEA Division held a regional Forum to explore the possibilities of regional co-operation against cactus moth (IAEA 2004j; IAEA, 2004p). Scientists from the USA and South Africa proposed an SIT based integrated approach to control this pest including the application of low impact insecticides, registered for use against cactus moth, the technique for effective artificial mass rearing and sterilization and a sex pheromone for pest monitoring and detection.

They also suggested a regional strategy for preventing the spread of cactus moth and for eliminating populations from the South East USA and the Caribbean. According to the proposed strategy, close and active co-operation should develop between Mexico and the USA, countries facing an imminent risk of introduction and establishment of this pest. OIRSA (Organismo Internacional Regional de Sanidad Agropecuaria) and NAPPO (North American Plant Protection Organisation) would facilitate the involvement of the Caribbean and Central American countries and of Canada in co-operative activities, while South American countries would participate through *ad hoc* mechanisms.

Finally, the IAEA, FAO, South Africa, the prickly pear industry and non-governmental organisations would uphold initiatives against cactus moth in prickly pear commercial production areas, via scientific, technical and financial support and would contribute to raising public awareness of the cactus moth problem (IAEA 2004p). The IAEA has been contributing since 2003 to Mexico's capacity and awareness building activities aimed at preventing the introduction of cactus moth, via technical co-operation and research funding. Its contribution has been available to other interested IAEA members as well (IAEA 2004a).

Additional support is being sought at the time of this report for what will be the first SIT programme motivated as much by concern for protection of biodiversity as by agricultural benefits.

4.3.4 Other Lepidoptera

The caterpillars of moths are some of the most damaging crop pests in the world. They can infest annual and perennial crops, forests and stored products causing substantial economic damage. Current control and abatement strategies involve the use of broad-spectrum insecticides on a vast scale and have led to problems of insecticide residue in food crops and caused substantial ecological damage to agricultural land. This ecological damage results from the loss of beneficial arthropods such as parasitoids, predators and pollinators. The loss of insect diversity can in turn have profound effects on vertebrate diversity as their food sources are absent or reduced.

Research on inherited sterility in moths is to support the development of environment-friendly alternatives to current control methods (IAEA 2001e). Whilst IAEA-coordinated or funded work focuses on genetic F_1 sterility, SIT is expected to be applied in combination with other Integrated Pest Management (IPM) techniques such as pheromone disruption, specific entomopathogens, host-plant resistance and natural enemy enhancement. In spite of some considerable successes, Lepidoptera are known to be quite radio-resistant and, in general, the doses required to induce full sterility significantly reduce the viability of adults. This emphasizes the importance of an IPM approach and the importance of complementary strategies.

The experiences with tobacco budworm and corn earworm over the past decades show the possibility of employing sterile releases for pest control, but the economics have hampered adoption of this approach for more than short-term field trials (Bloem et al. 2005).

Live female painted apple moths (*Teia* anartoides) irradiated for sterility were employed in traps in and around Auckland, New Zealand for monitoring purposes: for delimitation surveys, confirmation of eradication and subsequently for detection of an unrelated introduction, because the pest's pheromone had not yet been synthesised in a laboratory (Suckling et al. 2006). While the primary control method used in a successful eradication was aerial spraying of a *Bt*-based formula, the programme included release of sterile males during the 2003/2004 campaign (Suckling et al. 2004). Controversy resulted in the use of aerial spraying, as public health concerns were raised, so that SIT may be even more important to control future incursions.

Presently, only the pink bollworm is being mass reared, with over 80 million sterile male and female produced per week (during maximum production from May to September) by the USDA facility in Arizona. A summary of other moths targeted for SIT appears in Table 4.7.

Table 4.7 Summary of status of SIT for use against selected Lepidoptera pest species

Moth pests	Ecology	Status of SIT	Control options	Stakeholders and impact
gypsy moth (*Lymantria dispar*)	A serious pest of broad leafed trees in urban and forest conditions.	Diets and rearing techniques are established. F_1 sterility extensively tested and used in field programmes in the 1970s and 1980s. Considered to be too costly; never became operational (Bloem et al. 2005).	Chemical control and biopesticides.	Increasing damage from exotic introductions e.g. spread through USA and Canada.
pink bollworm (*Pectinophora gossypiella*)	Key pest of cotton.	A successful SIT programme has been operating since 1970 in California and the southwest USA as part of an IPM approach. SIT has been added to area-wide programmes in Texas. A less expensive diet is being developed. Field release of 50:1 reduces impact below economic threshold.	Chemical control most widely used (10-17 applications/year) outside the SIT control areas. Pesticide resistance is emerging. Sex pheromone mating disruptors and biocontrol agents used. Can be used with SIT in combined IPM approach.	High damage in many cotton production areas. E.g. most injurious cotton pest in Pakistan. (See Section 3.1.1 on funding for sterile release programme in the USA.)
oriental fruit moth (*Grapholita molesta*)	Attacks peaches, apple, nectarines, apricots, quince, plum and other fruits.	Mass rearing, diet and quality issues are all in place. Good sterility achieved, F_1 sterility under review. SIT highly effective against over wintering population.	Pesticides currently used are not very effective. Need other components to IPM to use with SIT. Mating disruption is used extensively in the San Joaquin Valley, California.	High in E. Mediterranean regions, Bulgaria. Direct damage to fruit plus the branches, causing long term impact.
cotton bollworm/ corn earworm (*Helicoverpa armigera*)	Serious pest of cotton, corn and over 80 other spp.	Advances made in China on diet, rearing system, irradiation doses. Problems with irradiated females. Irradiated males suffered 10 % loss of survival of in F_1, 35% in F_2.	India is starting to use genetically modified cotton varieties aimed at resistance to this pest. Pesticides used. Also hymenopterous parasitoids.	High damage in China, Phillipines and India; moderate in other areas.

Table 4.7 (Continued) Summary of status of SIT for use against selected Lepidoptera pest species

Moth pests	Ecology	Status of SIT	Control options	Stakeholders and impact
asian corn borer (*Osterinia furnacalis)*	Pest of maize or corn.	Laboratory level rearing established. Good performance of F_1 sterile males.	Combination of SIT with hymenopterous parasitoids shown to reduce damage from 28.2% to 3.6% in field trials.	Significant damage.
jute hairy caterpillar (*Spilosoma obliqua*)	Pest of jute, pulse, sunflower, soybean, groundnut, etc.	Various diets have been tested and best option is being refined. Quality of adults after irradiation is under evaluation.	Conventional pesticides (see also http://www.indiaagronet.com/ indiaagronet/crop%20info/jute.htm)	High damage in countries where jute is a crop, e.g. Pakistan and Bangladesh.
common cutworm (*Spodoptera litura*)	Polyphagous. Attacks recorded on 112 crops and garden plants from 44 families.	Diet is established and sterility tests are beginning.	Conventional pesticides and biopesticides (see also http://www.agrobiologicals.com/ glossary/Targ13.htm)	Significant damage.
diamondback moth (*Plutella xylostella*)	Attacks crucifers. May have genetic variability among worldwide populations.	Diet and mass rearing established. Suitable radiation dose found. F_1 sterility >80%, F_2 > 79%.	Prone to develop resistance to pesticides. Augmentative release of parasitoids promising component of IPM.	High damage levels to young plants. Practically cosmopolitan in distribution.
Sugarcane borer (*Diatraea saccharalis*)	Attacks sugarcane.	Lab work has led to optimism about mass rearing. Low dose radiation induces sterility.	Both biological and chemical control are currently used (e.g. South American countries).	Can cause 10% loss of sugar yield.
fall armyworm (*Spodoptera frugiperda*)	Attacks maize, sorghum, rice, wheat, barley etc.	Diets available, laboratory populations. Not yet mass reared. Good sterility levels achieved.	Conventional chemicals and biopesticides (see also http://entomology.unl.edu/ instabls/fallarmy.htm)	High level of damage. Brazil maize has 34% loss. 1970s losses in USA and Canada est. US$300 million per year.
cabbage webworm (*Crocidolomia binotalis*)	Attacks crucifers at all life stages.	Laboratory populations available, but not yet mass reared. Sterilization of males more successful (64%) than of females.	Conventional chemicals and biopesticides (see also http://www.extento.hawaii.edu/ kbase/reports/recommendations/ colecrops.asp)	Medium damage. Damage greater because it becomes widespread e.g.in Indonesia.

Sources: IAEA 1993; IAEA 2001e; and those noted in table.

4.4 The market for other plant pest species

4.4.1 Boll weevil

The boll weevil *Anthonomus grandis* Boheman (Coleoptera: Curculonidae) attacks upland or American cotton (*Gossypium hirsuitum* L.), which are varieties that account for 99 percent of cultivated cotton in the USA. Another cotton crop species, *Gossypium barbadense*, is also a host but is now principally used in northern Africa (Smith and Harris 1994).

The boll weevil also uses other host plants, all of which are in four closely related genera of the family Malvaceae**:** *Gossypium, Cienfuegosia, Thespia* and *Hampea* (Cross et al. 1975). In the USA the principal alternative host is *Cienfuegosia drummondii* Gray. In tropical areas the boll weevil is reported to use many more host species within the above genera (Smith and Harris 1994). An element of confusion may be introduced by the recognition of three taxonomic forms of the boll weevil, only one of which attacks cotton in the USA.

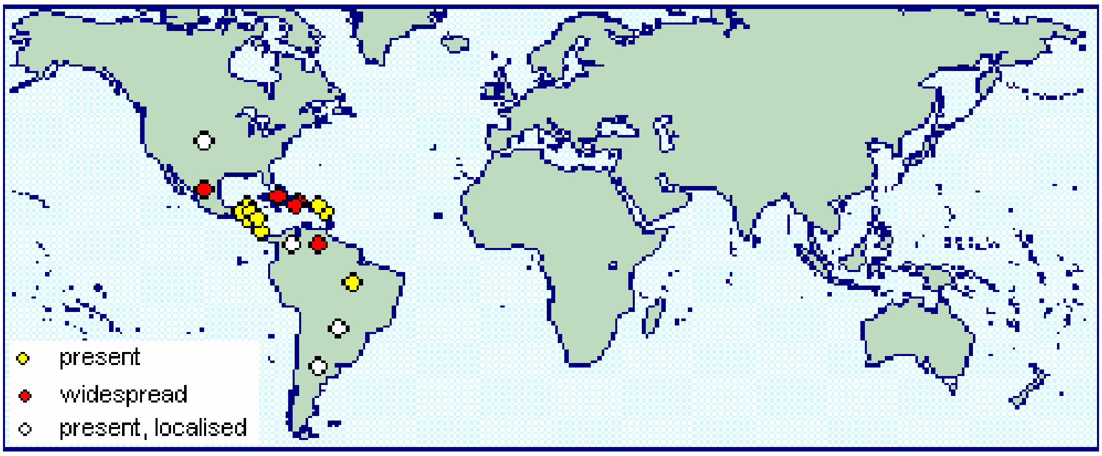

FIG. 4.13 Global distribution of cotton boll weevil (Anthonomus grandis) by country (rather than actual infested area) and prior to eradication from parts of the USA. (Map source: COSAVE 2002).

The boll weevil is thought to be indigenous to Central America. The form that attacks cotton in the USA is also present in the Caribbean (Hispaniola), Colombia, Venezuela and Brazil. The species is likely to be present in other South American cotton growing countries (Argentina, Bolivia, Paraguay, Chile and Uruguay), but formal records are sparse. Figure 4.13 shows in red the areas where boll weevil is known to be widely distributed (COSAVE 2002), although it is shown by country rather than by the actual infested areas. African cotton growing areas have no reported infestations of the boll weevil.

The boll weevil is thought to have entered the USA from Mexico in 1892 and was first recorded in Texas in 1894. Its subsequent spread encompassed the majority of cotton-growing areas in the country. Since the boll weevil was first noted in the USA, it is estimated to have caused US$13 billion in economic damage. Recent annual control costs are in the region of US$300 million. With the IPM control programmes outlined in Table 4.8 the southeast and southwest of the USA and a portion of northwest Mexico are now free of the boll weevil (Cunningham and Grefenstate 2000). Presently, around 8 million acres are under the eradication programme and 4.5 million have been declared free of the pest (National Cotton Council 2001a).

Current efforts in the USA focus on eradication from the cotton growing areas of south central USA. If the current US eradication program is successful, Central America and Mexico will remain a potential source of reintroduction. The maintenance of a broad cotton-free belt would impede this, but given the length of the Mexico-US border pushing the distribution of this pest species further south would be of enormous benefit to both countries.

Description and biology

The entire life cycle of the boll weevil can last from 18 to 55 days or more depending on environmental conditions. High temperature and humidity favour development. In the optimal part of its range seven generations can be produced in a single year. Females can produce up to 200 eggs, which are oviposited singly in flower buds or within squares or bolls. The larval stage causes the principal damage whilst feeding within the boll. Adult feeding damages the boll casing and can allow incursion of secondary infections. Oviposition scars are similar to adult feeding damage, but are sealed by the female to protect the egg.

Adult weevils spend the winter in hibernation (diapause), usually in plant litter and surface trash surrounding field margins and farm buildings. Seasonal flooding reduces overall population size in these regions. A night temperature of 20-21°C is required for emergence from diapause. Dispersal is usually induced in late season when weevil numbers and hence competition for food are high. The adult can fly and cover substantial distances. Adults have been captured 600m above ground and are recorded to have dispersed 48 km in a single day and 272 km during a six-week period (Smith and Harris 1994).

Boll weevil are very mobile. Knipling (1979) produced models showing that if 10 percent of a boll weevil population remained after suppression, this is enough to redistribute to and repopulate the entire area in less than one growing season.

Damage and economic impact

The direct economic benefits of boll weevil eradication are two-fold: yields rise and pesticide application (prophylactic and curative) falls. These effects are permanent provided the pest is not reintroduced. In areas of endemic infestation 7 to10 percent of the crop is lost annually, although this may occasionally be much higher. Larval feeding causes boll drop or damage to the lint inside retained bolls. Infested fields can produce large, leafy plants, with little fruiting crop.

Eradication of the boll weevil under the current IPM programme is estimated to result in annual combined economic benefits of US$780 million in the USA. National Cotton Council figures suggest that this amounts to accrued benefits of US$12 per dollar spent on eradication (National Cotton Council 2001a).

In the USA the boll weevil accounts for most of the chemical use on cotton and eradicating this pest can lead to reductions of 40-90 percent of insecticide use. In areas where eradication has been successful there have been additional benefits to reduced insecticide application; beneficial insects such as parasitoid wasps and ladybeetles that prey on other cotton crop pests resurge in numbers. Currently the cost of crop protection chemicals in the USA amounts to between 16 and 20 percent of the cost of production, with application labour and machinery costs adding another 5 percent (National Cotton Council 2000). The recent falls in cotton prices and cotton futures and the bleak industry outlook will provide an incentive to reduce these pest management costs (National Cotton Council 2001b).

Current area-wide eradication programme

A program to eradicate the boll weevil from 10 million acres (of 13 million acres of cotton crop) infested in the USA began in 1963 and is managed by APHIS. Eradication of the pest from the USA was originally predicted for 2016. This program employs an array of techniques including pesticide use (ultra-low volume malathion) and pheromone sex-lure attractant traps, laid out in Table 4.8. In 1994, when 3.24 million ha remained infested the National Cotton Council requested an accelerated program with a view to eradicating the pest from the USA by 2003 (USDA/APHIS 2001).

Table 4.8 Current US boll weevil eradication programme stages

Year	Stage	Method
1	Initiation	Autumn applications of malathion starting in August or September over almost 100% of acreage
2		Full season pheromone trapping and malathion treatments on 70-90% of acreage during spring, mid-season and autumn
3		Full season pheromone trapping and malathion treatments on 20-30% of acreage
4		Full season pheromone trapping and malathion treatments on 10-20% of acreage
5-6	Eradication confirmation	Continued pheromone trapping, selected malathion treatment on 1-10% of acreage
7-8	Post eradication	Reduction of trapping density, response to any reinfestations

At its inception the program was funded half and half from federal funds and cooperating partners (grower and state organizations). In 1983 the federal share fell to 30 percent. Since 1997 this percentage contribution was no longer guaranteed and began to be replaced by a favourable loan structure enabling growers to defray the high initial cost of participation over seven or eight years (Cunningham and Grefenstate 2000).

Possibilities for SIT

Early attempts to use SIT against boll weevil were not successful due to continual reinvasion of the pest and high population levels (Pedigo 2002). Problems encountered included the concern that release of sterile boll weevil was “only” 98-99 percent effective, number of small farmers who did not understand the new approach to control, unreported blocks of cotton (due to tax and levy issues), some wild and ornamental cotton hosts, volunteer cotton from fallow fields and reinvasion from Mexico. A report from the National Academy of Science condemned the eradication effort due to some 15 remaining individuals in the field trial area (Losey and DiTommaso 2002). The USDA programme shifted from “eradication” to area-wide control after these events.

In the mid-1990s SIT was still considered to be not sufficiently advanced for this species to replace or complement the approach outlined in Table 4.8, although APHIS considered it important to continue working to improve SIT for this species (USDA/APHIS 1996). The USDA/ARS has established that sterile males remain competitive with wild males and that a life span of two weeks under field conditions after release can be expected (Villavaso et al. 1998). The SIT has become an increasingly viable option for pest control over the duration of the APHIS led program and has the potential both to assist eradication and to form part of a ‘barrier method’ for preventing the boll weevil’s re-entry into eradicated zones.

Increased urbanization of American farmland has led to more contact with environmentally sensitive areas in which pesticide use is not possible. The genetically modified *Bt* cotton

(Bollguard by Monsanto) has increased its market share and whilst effective against Lepidoptera pests, the modification has marginal effects on boll weevil. This situation, along with the potential of a backlash against GM crops, opens the door to SIT strategies. Sterile boll weevil would be a more appropriate control method in parks or environmentally-sensitive areas (Klassen and Curtis 2005).

A history of cooperative funding for pest control programs in the USA and Mexico gives a positive outlook for successful continuation of the integrated programme, including use of SIT. There is also potential for SIT to contribute to combating the pest in South and Central American countries, where its economic importance is high. While the high cost of control has the potential to favour SIT and could contribute to barrier methods preventing reintroduction, a recent decline in US mill use and falling prices have contributed to high retained stock levels. This in turn could lead to a reduction in cotton acreage in future years (National Cotton Council 2001b).

Table 4.9 Cotton production and consumption in South America for 1999/2000 (USDA 2001)

Country	Production (1000 MT)	Consumption (1000 MT)
Argentina	130 000	85 000
Bolivia	3 000	6 000
Brazil	600 000	850 000
Paraguay	85 000	9 000
Chile/Uruguay	NA	25 000
Total	818 000	975 000

There are potential future markets for application of SIT in eradication or suppression programmes of boll weevil in both Central and South America. The substantial production levels of several countries (Table 4.9) would be increased by sophisticated pest control. Use of SIT in place of continual pesticide applications would also benefit the countries' wider population and environment. While the high cost of control has the potential to favour SIT and could contribute to barrier methods preventing reintroduction, a recent decline in US mill use and falling prices have contributed to high retained stock levels. This in turn could lead to a reduction in cotton acreage in future years (National Cotton Council 2001b).

In the USA cotton growing is exceedingly well organized and the history of the USDA/APHIS eradication program has reinforced this. The National Cotton Council is the principal link with growers, but each cotton producing state has extensive links with federal and research agencies and cooperates actively with adjoining states. In 1997, Mexico instituted a grower and government joint funded eradication program in the northeast state of Tamaulipas. This is indicative of a high level of organization and of a willingness to enter into cooperative pest management ventures by this country.

However, SIT may not be developed unless the current approach using trapping and pesticides becomes less feasible. While malathion will not be available in some countries, other pesticides have been studied as possible substitutes in boll weevil area-wide programmes. The future of SIT against this pest may be hampered more by the success of the already widely used technology rather than any limitations to mass rearing and sterilization of the species that could not be overcome with further development.

4.4.2 Other plant pest species

The onion fly (*Delia antiqua*) is mass-produced in Nieuwe Tonge, the Netherlands. It is a local strain and has been produced since 1981. The production total has been estimated as approximately 400 million per year, or up to 7.5 million pupae per week (male and female), which can be held in diapause. Each pupa is subjected to 30-40 Gy of radiation for sterilization. The weekly production is sufficient to treat about 3900 ha. This species has been used in local area control schemes for a number of years (See Box 3.2 in Section 3).

Other plant pest species that may be used in SIT are under study or already in production. The production levels remain experimental, but demonstrate the possibility of commercial production. Markets for these species must be better studied before private investment is likely to occur.

The sweet potato weevil (*Cylas formicarius*), a significant pest of sweet potato, spread from India throughout Asia years ago. Japan's control programme began in 1994 with MAT using an attractant with insecticide-impregnated blocks. This approach was not successful by itself as the insects did not feed on the attractant, so that the approach of SIT was necessary (Teruya 2002). Sweet potato weevil is mass produced in Okinawa, Japan. The production facility has been in operation since 1998, and produces approximately one million pupae per week (male and female). Mature adults are sterilized by being subjected to 200 Gy of radiation then dispersed by aerial release using helicopters. The release rate has been 500 to 2000 sterile insects per ha. Since 2001, one million sterile adults are released weekly, which has achieved a ten fold decrease in wild populations. The limiting factors for increased use of SIT against sweet potato weevil at this time are the number of eggs produced on the artificial diet and survival time of the sterile adults after release. The programme has also been working on improvements in the MAT approach for more success from the integration of measures (Teruya 2002).

The West Indian sweet potato weevil (*Euscepes postfasciatus*) is also produced at the production facility in Okinawa. Less than one million pupae per week are produced (male and female) during this pilot phase. The pest did not adapt to artificial diets provided to date, thus driving up the costs of production. Male pupae are subjected to 40 Gy of gamma and adults 150 Gy. Additional research also is required for SIT to be fully exploited against this species (Teruya 2002).

Shimoji and Miyatake (2002) studied the adaptation of the female West Indian sweet potato weevil to artificial diet for over 14 successive generations in relation to its oviposition behaviour and the success of SIT. Their study suggests that the fertility of female insects increased during the test period. Egg hatch, ranging from 85 to 95 per cent, and adult yield, ranging from 30 to 60 per cent, were constantly high. In addition, the comparison of fertility and pre-oviposition periods revealed that artificilly reared females of the 14^{th} generation oviposited more eggs and earlier in life than females from the base stock. This was due to an increase in frequency, by 100 per cent, of insects that laid eggs without standard oviposition substrate in the artificially reared strain (IAEA 2004f).

Another pest of increasing concern is white fly (*Bemisia tabaci*), not only due to the damage it can cause, but also to the diseases that it can vector. According to the IAEA worldwide directory, the white fly is mass-produced in Rome, Italy, with a weekly production of 500 000 insects (male and female). Adult insects are subjected to 60 Gy of radiation for sterilization. Calvitti et al. (2000) reported that greenhouse trials with sterile white fly did not achieve complete eradication but did suppress the population considerably after 90 days of 10-day intervals. The SIT against white fly was more successful in greenhouses not exposed to migratory pressure, which could be reduced by use of screening.

The red palm weevil (*Rhynchophorus ferrugineus*), a serious pest of coconut palms in Asia, entered Saudi Arabia around 1985 and from there, by the end of the 1990s, moved throughout the region. It is a significant pest of date palm and other palm varieties. Recently, it has become established in Spain. Pilot testing has taken place in India, under the leadership of the Bhabha Atomic Research Centre in Mumbai, India (Hendrichs 2006). As other types of control have proved ineffective or inadequate in some way, numerous countries have petitioned the IAEA for assistance in developing SIT against this pest, including the seven countries that comprise the Cooperative Agreement for Arab States in Asia for Research, Development and Training related to Nuclear Science and Technology (ARASIA). A regional project to evaluate the feasibility of SIT and other control measures for the red palm weevil in Iraq and Jordan was approved under IAEA's ARASIA project portfolio to begin in 2007.

Initial research has been conducted on other pests, although mass rearing has not begun. The sterilized pest of greenhouse crops, *Liriomyza trifolii* (Diptera: Agromyzidae) has been found to essentially match performance of unirradiated males in tests conducted at the University of California at Davis (Kaspi and Parrella 2002). Sterility was achieved with a dose of 155 Gy for both sexes.

4.5 The market for sterile tsetse fly

4.5.1 Biological situation

The tsetse fly (a common name referring to any species in the genus *Glossina*) is confined to Sub-Saharan Africa and a reported temporary incidence in a small area along the south western coast line of the Arabian Peninsula. It is a serious pest because of its role as the vector of the trypanosome blood parasite, which causes trypanasomiasis ("sleeping sickness") in humans and "nagana" in livestock, particularly cattle. This is a highly pathogenic disease, which attacks livestock of high unit value – effectively one bite of an infected fly can destroy the value of a head of cattle, allowing the fly to do great damage at very low population densities.

The tsetse fly has several distinctive biological characteristics. A single female may typically produce as few as an average 5.5 pupae in a lifespan of over 2 month (Buxton 1955). Atypically, therefore, the tsetse fly is slow to expand its population and often prevalent at low densities as compared to other key insect pests. Even at substantially reduced fly population densities, however, tsetse are still efficient vectors. Because it is the virulence and vigour of the parasite, not the fly, which is instrumental, so that low densities are capable of causing significant damage.

For this reason, returns on control at low population densities, although accruing benefits throughout the progression from a very low population level to complete eradication, are not proportional to the achieved reduction and the final step of eradication brings disproportionate benefits. Unlike other biting insects both sexes feed only on vertebrate blood throughout their entire adult life.

The tsetse's unique biological factors have consequences that differentiate it from all other pests.

First, the muscles of the tsetse fly, including its flight muscles, uniquely consume the amino acid proline, not sugar, in respiration. Flight duration is limited by the availability of free proline to ten minutes or less (an average 30 minutes per day), after which the fly must rest while new proline is catabolized from its fat reserves[13].

Second, unlike most blood-feeding insects, adult males as well as females feed on blood and are potential vectors.

Third, the tsetse fly is viviparous. Each female produces a single larva every nine or ten days, which is nourished to maturity inside the like female's body in a way analogous to the reproduction of mammals. The larva is "born" fully developed, and burrows into the ground immediately to pupate without further feeding. The new adult emerges after 30 to 40 days, dependent on temperature. Larvae therefore are exposed outside the mother's body for only a few minutes before they burrow into the ground, making the egg, larval and pupal stages effectively inaccessible to direct control. Also offspring are produced slowly, one at a time, in contrast to the large reproductive production of most pests, and unlike them the insect is considered "*K*-selected" in ecological parlance. Like other *K*-selected organisms, tsetse appears able to maintain itself stably at low densities depending on parameters such as species (ecology and behaviour), the suitability of terrain and availability of hosts. A density of five flies per km^2 has been estimated as the minimum population that still allows mating (J. Slingenbergh, pers comm 2001).

The above biological factors and the species and site-specific ability of flies to advance into "pest free" areas should be taken into account when considering an approach that aims at the creation of a tsetse free zone in mainland Africa and would possibly involve the SIT as one of several components of an integrated area-wide intervention campaign.

4.5.2 Requirements for applying SIT to tsetse

The biological factors that result in low-density populations are the same ones that make mass rearing of the insect challenging. Low production rates are the root of long start up periods before a mass rearing facility could supply an SIT programme. Only males are released and the breeding population of females must be carefully supported due to this low productivity.

Male tsetse flies can transmit trypanosomosis and so the inundative releases of males may temporarily contribute to disease transmission. Yet as a result of pre-release population suppression the total number of vectors present is substantially reduced before initiating SIT. Pre-release suppression aims at reducing the target tsetse population down to or, if possible, below 4 percent of the original vector population density. There was no indication on Zanzibar that the release of sterile males increased trypanosomosis prevalence (Dyck et al. 2000). The risk of males transmitting trypanosomosis is low as the lifespan of irradiated males is 7 to 14 days, whereas the incubation period of the disease is 11-30 days, depending

[13] In the overall evaluation of the prospects for tsetse SIT, a good deal hinges on how far the Zanzibari success may be regarded as representative for projects on mainland Africa. Earlier efforts (Dutoit 1954; Spielberger, Na'isa and Abdurrahim 1977) using conventional vector control methods confirmed that tsetse fly species can be sustainably removed. In other areas reinvasion was recorded and further success of integrated area-wide intervention projects on the African continent will largely depend on the identification of isolated or confined fly populations in areas with high potential for agricultural development.

on species and temperature. This can be further reduced by feeding SIT males before release so that the peritrophic membrane is developed, rendering the individuals more refractory to infection for a period. The reduction in risk can be further enhanced by including trypanocidal drugs in the sterile tsetse pre-release blood diet and by timing releases in relation to satiation ("fedness") so that males are maximally disposed to mate and minimally disposed to feed. In the future it may be possible to inoculate the release strain with a recombinant form of the symbiont *Sodalis*, which makes them refractory for trypanosomosis transmission (Aksoy et al. 2001).

While other groups (e.g. Lepidoptera) are more likely to suffer disease outbreaks in the rearing colony, tsetse appear to be less susceptible to biological contamination. Entire colonies of tsetse can be lost, however, over the quality of diet. Blood with a trace of (often unrecorded use or illegal use of) pesticides or parasiticides such as ivermectine can wipe out a colony in short order. A simple bioassay (Feldmann 1994) enables the elimination of blood batches with adverse components from fly colony feeding.

Blood diets are typically irradiated to reduce other types of pathogens, but the gamma dose administered for this must be much higher than that used for reproductively sterilizing the insects (e.g. 1.0-1.5 kGy vs 120 Gy). Ethiopia intends to use local supplies of blood for its production. It will need an estimated 360-450 litres per day for a colony of 10 million females. At this time, a colony exceeding 50 million females might result in blood diet becoming a limiting input. Alternative supplies of blood diet from other countries in the region, preferably having regulated slaughter house systems, may be in the position to satisfy the increasing demand for frozen blood through provision in reefer containers (e.g. South Africa). IAEA is conducting research on blood substitutes that will avoid this and other issues. (See discussion of risks from rearing animal pests in Section 5.)

Although the insemination by one male fly is sufficient for a tsetse fly female to fertilize all eggs that she ovulates in her life span, a few tsetse females may re-mate mainly in the first days of their life. After the first ovulation which occurs about day 9 post female emergence, the uterus through which any subsequent spermatophore has to pass to reach the female's spermatheca is blocked most of the time by a fertilized egg or a developing larvae in utero. In the Zanzibar eradication of *G. austeni* the overflooding ratio of sterile to wild males was in the order of 10:1 (Vreysen et al. 2000). In females that are multiply mated, sperm from both matings can be used, and there is some evidence in other insects that fertile sperm may prevail over sterile in a female mated with both sterile and fertile males. The incidence of multiple mating in tsetse in laboratory experiments is so low that it is not possible to determine if sperm precedence is also present in tsetse. As in other SIT programmes the ratio of sterile to wild males therefore will be maintained at a continuously sufficient high level throughout the eradication period in order to ensure that sterile males always outnumber wild fertile males, thus minimizing the risk of fertile matings.

There are 22 species and 9 subspecies of tsetse (Nagel 1995). Over 86 percent of the tsetse infested area harbours from one to three species, and less than 5 percent harbours five or more species. Figure 4.13 shows the predicted distribution of tsetse species in terms of the occurrence of single or multiple species. (Given the lack of data of actual occurrence of tsetse, the method for arriving at these predictions is explained in detail on the ERGO Web site.)

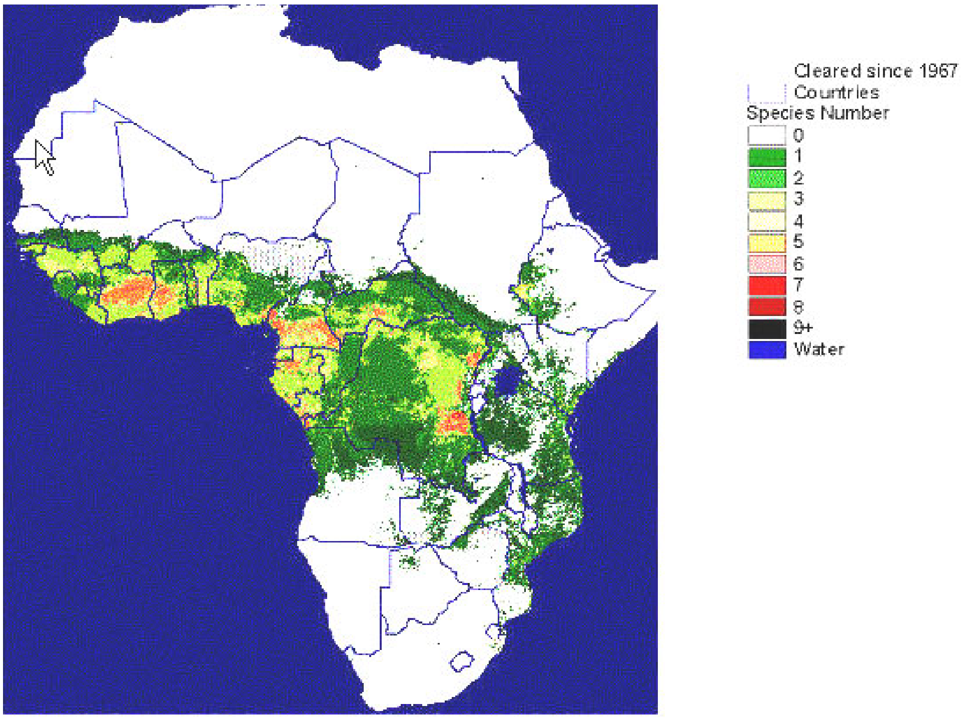

FIG. 4.14 Predicted distribution of tsetse in terms of number of species.
White is no presence, greens show one to three species.
(Source: Environmental Research Group (ERGO), Oxford University.
http://ergodd.zoo.ox.ac.uk/tseweb, select for all species.)

The different species of tsetse are sufficiently similar in their rearing requirements that to rear different species a factory would need only minor modifications to temperature, humidity and rearing protocols, and probably not to structures or hardware. Tsetse SIT programmes are always single sex (male) releases, so as there is minimal interspecific interaction between males there is minimal effect on multi-species releases. Any tendency to satyrism (selection by wild females of non-conspecific males) would enhance the effect of the releases as all observed tsetse hybrid matings produce a high proportion of sterile male hybrid offspring. While most SIT programmes will consist of releases of one species, a successful SIT operation was conducted in Burkina Faso in the 1980s that eradicated three species of tsetse simultaneously.

The locations of all of the sterile tsetse production facilities currently operating or in advanced planning stage are shown in Section 5, along with other production facilities. The Ethiopia facility is designed to breed approximately 10 million tsetse females in colonies that supply sufficient males for release over 10 000 km^2, possibly 15 000 km^2 at a time. The aim is to reach full capacity of the six modules built at Kaliti (pictured in Section 5) to eventually cover the entire tsetse infested area of 180 000 km^2 to 200 000 km^2 in Ethiopia. The requirements for the approximately 400 000 km^2 of infested area in the rest of eastern and southern Africa will be clarified in stages. An effort was made to estimate the needs for sterile males and the resulting requirements in fly production capacity for Ethiopia, Uganda and Kenya through 2012 at a PATTEC regional harmonization meeting in Kenya, October 2005, as presented in the tables below.

In recent years substantial improvements have been made in the technology of mass-reared tsetse production. A FAO/IAEA Coordinated Research Project has focused on quality of reared, treated, transported and stored insects, to bring together the disparate strands. Many detailed aspects have been improved - injection-moulded cages, hexagonal instead of round feeding cage floors to allow fuller use of feeding media, attachment of netting by hot melt instead of solvent glues to avoid the use of volatiles, and the development of automated, rail-based feeding trolleys have all increased efficiency. These have been incorporated into a prototype fly holding and feeding unit, "TPU3" (Tsetse Production Unit 3), which can be installed in stationary tsetse factories or in climatised reefer shipping containers to allow for the unit to be moved.

Improvements in the automated stocking of production cages with the most suitable sex ratio (four females per male) have obtained a ten-fold increase in speed over manual handling, and similar improvements are still being developed. Sources (currently unpublished) indicate that other mass production improvements have cut costs by 70 percent, and a cost reduction per sterile male fly produced from a current level of US$0.07-0.14 to one of US$0.05-0.09 seems realistic.

Although artificial diets for tsetse, as a blood drinker and quite fussy (pig blood appears less productive than cattle blood, for example), may never reach the facility of artificial diets for screwworm, improvements have been made. Techniques for the choice, treatment and storage of blood for nutrition have been greatly improved by research at the FAO/IAEA Laboratory. Mixtures of cow and pig blood have been found to be superior to either used alone. The use of pasteurisation instead of gamma-irradiation to reduce the bacterial load of blood has progressed (for example, fast cooling allows the use of high temperatures for pasteurisation without coagulation). Evaluation technologies have also advanced - the fitness of males following rearing, treatment and storage, can be assessed by taking spermathecal values from mated females, allowing the insemination potential of males to be accurately assessed.

All of the prognoses for the prospects for tsetse SIT may be altered by technical improvements, which might dramatically increase its productivity or effectiveness. By their nature the prospects for these improvements cannot be safely predicted. It appears at the moment, however, that improvements in field technology such as attractants, and genetic technology such as symbionts[14] and sterile cross-breeds, will in the near future produce results less readily and reliably than in the rearing of sterile flies.

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[14] In theory, the costs of SIT may be defrayed, though the role of nuclear technology diminished, by prospective plans to obtain sterile matings by cytoplasmic incompatibility (CI) rather than irradiation. Matings are sterile if the male is infested with the parasite Wolbachia and the female is uninfested, or infested with a different strain, or to a lower density or infestation order. So infested males will obtain sterile matings as long as the wild females are differentially infested or uninfested (this requires careful sexing of releasees - infested females could infect the wild tsetse population with the released Wolbachia strain resulting in the released males being able to fertilize the newly infected wild females). Apart from the technical and political impact of losing support from the IAEA expert community along with laying down the nuclear technology, CI males are assumed to be more competitive in the wild, and thus more effective for control, than irradiated males (Aksoy et al. 2001). There are, however, a number of uncertainties associated to this technology such as the need for eventual Wolbachia replacement or the possibility that some females can accept different Wolbachia type males. In addition, it is necessary to take into account that CI males may live longer than irradiated males and may contribute to increase transmission. While the vast benefits of automation in the current sterilization facilities are still being recognized, it is unlikely that such a shift in production strategy will take place in the near future.

Table 4.10a. Supply and demand of various tsetse species for sterile insect control in East Africa.

	Ethiopia	**Kenya**	**Uganda**	**Tanzania**
Location	Addis Ababa Kaliti	Nairobi Muguga	Tororo	Tanga
Physical facility	Temporary insectary 130 m² 2 of 6 modules operating; each 1 059 m²	2 breeding rooms ready 100 m² 3rd BR under renovation ca. 40 m²	2 breeding rooms ready 50 m²	3 insectaries 300 m²
Fly rearing capacity	2.5 million colony females	250 000 colony females	150 000 colony females	2 million colony females
Species and present colony size	*G. pallidipes* – 30 000	*G. pallidipes* – 20 000	*G. f. fuscipes* – 4 000	*G. austeni* – 80 000 *G. pallidipes* – 1 000 *G. brevipalpis* – 1 500 *G. m. centralis* – 4 000
Personnel				
Scientists	2	6	2	10
Technical staff[a]	11	15	6	32
Support staff[b]	12	3	2	9
Source of Blood	Distance 15 km Weekly capacity: 1 000 litres	Distance 50 km Weekly capacity: 200 litres	Currently no local blood source	Distance 5 km Weekly capacity: 200 litres Additional sources 350 km distance; >1 000 litres / wk
Gamma source	GC-220; plans to purchase GB-127	GC-220 under delivery	Supply of gammacell currently not possible	GC-220

[a] Laboratory technicians, lab attendants, tsetse diploma holders, etc.
[b] Electrician, plumbers, cleaners, drivers

continued…

Table 4.10a (Continued). Supply and demand of various tsetse species for sterile insect control in East Africa.

	Ethiopia	**Kenya**	**Uganda**	**Tanzania**
Colony sizes	*G. pallidipes* 500 000 *G. f. fuscipes* 100 000	*G. pallidipes* 200 000	*G. f. fuscipes* 100 000	*G. austeni* – 25 000 *G. brevipalpis* – 10 000 *G. pallidipe*s – 50 000 *G. m. centralis* – 50 000
Lab activities	Mating competitiveness tests Blood QC / QA Recruitment of staff	Mating competitiveness tests Blood QC / QA	Recruitment of staff (3 Scient.; 10 lab techn.; 4 support)	Self sufficiency regarding the (local) availability of blood
Field activities	Test releases June 2006	Test releases April 2006	Collection and colonization of local *G.f.f.* strain for competitiveness tests	Collection and colonization of local *G. swynnertoni*
Plans – for end 2008 **Colony sizes**	*G. pallidipes* 3 000 000 *G. f. fuscipes* 800 000	*G. pallidipes* 250 000	*G. f. fuscipes* 150 000	*G. austeni* – 20 000 *G. brevipalpis* – 50 000 *G. pallidipe*s – 150 000 *G. m. centralis* – 150 000 *G.* swynnertoni – 15 000
Major constraints	SH virus problem Shortage of trained staff Delay in completion of insectaries	Shortage of equipment (trolleys, etc.) Vehicle specially for lab work Stand by generator	Lack of permanent staff Erratic supply of power Delays in insectary construction Absence of radiation protection legislation	SH virus (*G. pallidipes*)
Training needs	Short- and long-term training on technical and management issues	Short- and long-term training on technical and management issues	Short- and long-term training on technical and management issues	Short- and long-term training on technical and management issues

Table 4.10b. Estimated sterile tsetse fly needs by country[a]

	Ethiopia	**Kenya**	**Uganda**
Test releases (weekly No. st.m. for min 8 weeks)			
2006	(*G.p.*)15 000	(*G.p.*)8 000	
2007			
2008	(*G.f.*) 10 000	(*G.p.*)15 000	
2009			15 000
2010		(*G.p.*)15 000	
Operational releases (required weekly No. of st.m. – for 78 weeks)			
2007	(*G.p.*)100 000	(*G.p.*)20 000	
2008	(*G.p.*)250 000 (*G.f.*) 60 000	(*G.p.*)25 000	
2009	(*G.p.*)380 000 (*G.f.*) 60 000	(*G.p.*)700 000	
2010	(*G.p.*)500 000	(*G.p.*)750 000	1 000 000
2011	(*G.p.*)750 000	(*G.p.*)750 000	1 000 000
2012	(*G.p.*)1 000 000		1 000 000

[a] Not established (2006) for Tanzania. Besides the above, there will be need for establishing colonies of other species, such as *G. brevipalpis*, and to conduct test releases, etc.

The above translates in the following required colony sizes for the involved countries:

	Ethiopia	**Kenya**	**Uganda**	**TOTAL**
2006	200 000	120 000		320 000
2007	1 000 000	200 000		1 200 000
2008	3 500 000	400 000		3 900 000
2009	4 500 000	7 500 000		12 000 000
2010	5 500 000	8 000 000	200 000	13 700 000
2011	8 200 000	8 000 000	10 000 000	26 200 000
2012	10 000 000		10 000 000	20 000 000

Table 4.10c Administrative and institutional arrangements for sourcing flies

Option 1: (supplier – customer option)	Option 2: (corporate option)
(a) Ethiopia will produce *G. pallidipes* and *G. f. fuscipes* to supply Ethiopia, Kenya, Uganda and Rwanda (b) Tanzania to supply *G. f. fuscipes* to Uganda, Tanzania, Kenya and Ethiopia	Member States will contribute both financial and human resources to Ethiopia and Tanzania to enhance the production and the maintenance of G. f. f. and G. p. colonies
Implications: Mass-rearing facilities will be maintained by the respective Governments and sourcing of flies by other participating countries will be at cost-recovery (countries will purchase the flies)	Implications: The sourcing will be at no cost
The detailed financial implications for both scenarios would need to be worked out. In addition to 1-2 mass rearing centres there will be a need to establish seed colonies of the required species that should be maintained at a size of not less than 200 000 colony females, preferably at a site separate from the mass-rearing centre.	

4.5.3 Economic, social and environmental considerations

The costing of tsetse damage is unusually complicated and rich in interactions and "knock on" effects. The problems of economic costing of tsetse management projects (PAAT 2002) include issues of discounting and amortization; economies of scale (including perimeter:area ratios); the need to estimate elasticities for changes in total output with changes in stocking densities; the dynamics of situations where stocks would change independent of tsetse management; the estimation of add-on benefits (for example, tick management from insecticides); and whether and how to include indivisible, overhead costs such as strategic research. Cases, and the cost:benefit outcomes, of particular interventions are highly dependent on local conditions, and the overall picture is very fragmented: generalisations are hard and there are always exceptions.

The FAO Resolution on PATTEC (2002) estimated annual losses to tsetse and trypanosomiasis of US$4.5 billion (IAEA 2002c; 2002g). Costing of losses can include any or all of the following (Swallow 2000).

Direct:

- Human disease (see also Section 4.7). 1999 estimates are of 500 000 people infected with sleeping sickness and 50 million are at risk. Apart from the immense and unquantifiable human suffering and economic impairment, this is thought to incur direct financial costs of treatment of US$50 million per year (at US$100 per case) and of surveillance of US$35 million (at US$0.9 per person for 70 percent of those at risk).
- Animal production. Direct annual losses, in meat and milk production and the costs of controls, have been estimated as US$0.6 billion to US$1.2 billion (in 1994) and US$1.34 billion (in 1999). On infection, even when the disease is not fatal, meat and milk production are reduced by at least 50 percent.

- Animal traction. Losses to traction can be particularly serious, and the contribution of tsetse control to cultivation may be its greatest benefit. Draught power is able to increase cultivated areas by 20 times over human-powered cultivation, and may be as much as 50 percent of the value of cattle (Swallow 2000).

Indirect:

- Manure. The role of manure, alongside traction, as a benefit of animals to cultivation, is often mentioned but not quantified.

- Cattle management. Generally speaking trypanotolerant breeds, largely preferred in areas at risk, are less productive than more susceptible breeds. On Zanzibar there are plans to introduce higher production but more susceptible breeds due to the eradication of tsetse.

- Land use. Losses by the exclusion of cattle from affected areas are estimated as 90 million head. Much of the land currently empty of herds because of tsetse is among the underexploited land with the greatest potential in Africa for agricultural development. Land vacated by cattle that can move into tsetse-cleared areas may also be cultivated. In one Ethiopian village, after a control project reduced infestation to less than 10 percent of its start level, herders moved cattle into pastures further from the village, and the volume of land under cultivation near the village increased (Swallow 2000).

Table 4.11 shows the total estimated head of cattle and areas of land and that at risk due to predicted presence of tsetse, in the 37 African countries where tsetse is endemic (PAAT 2001). Figure 4.14 expresses the cattle holdings overlaid with the tsetse infestation, showing areas where cattle are at risk.

The complexities of economic assessments have led experts to urge caution and to emphasise that few generalisations are without substantial exceptions.

All these impacts can interact with social differences and social modulation. Cattle serve as social status in many parts of Africa, and are often used as security on loans, increasing capital liquidity. As a result of the interaction of human and animal consequences, and of direct and indirect losses, the synthesis of total damage, and thus of the benefits of control, is complex. Econometric integration techniques do exist, however, for example of milk and meat production with the benefits of draught power and cattle movement into areas (Shaw 1990 and 2003).

Table 4.11 Numbers of cattle, numbers in infested areas ("at risk"), total area and infested area in the 37 countries where trypanosomiasis is endemic (PAAT 2001)

Country	**Head of cattle** (million)			**Area** (thousand km^2)		
	Total	At risk	%	Total	At risk	%
Burkina Faso	4.522	2.422	54	282	167	59
Mali	5.725	1.766	31	1317	204	15
Chad	5.079	1.558	31	1325	197	15
Senegal	2.913	0.721	25	204	80	39
Gambia	0.246	0.201	81	11	11	94
Niger	2.100	0.035	2	1246	5	0
Sahel total	**20.585**	**6.703**	**33**	**4385**	**664**	**15**
Nigeria	19.610	5.084	26	926	587	63
Guinea (Conakry)	2.200	1.702	77	249	248	100
Ghana	1.184	1.184	100	242	238	98
Cote d'Ivoire	1.312	0.996	76	326	325	100
Benin	1.400	0.603	43	117	117	100
Togo	0.296	0.296	100	58	58	100
Sierra Leone	0.400	0.189	47	640	627	98
Liberia	0.036	0.022	61	97	97	100
Guinea-Bissau	0.475	0.254	53	33	31	94
West total	**26.913**	**10.330**	**38**	**2688**	**2328**	**87**
Congo (Brazzaville)	0.072	0.044	60	343	343	100
DR Congo (Kinshasa)	1.411	1.411	100	2348	2256	96
CAR	2.992	2.344	78	627	624	99
Gabon	0.039	0.013	34	266	263	99
Cameroon	4.900	2.612	53	471	399	85
Equatorial Guinea	0.005	0	4	25	25	99
Central total	**9.419**	**6.424**	**68**	**4080**	**3910**	**96**
Sudan	22.500	3.209	14	2598	258	10
Ethiopia	29.900	3.225	11	1147	176	15
Somalia	5.200	0.344	7	640	22	4
Horn total	**57.600**	**6.778**	**12**	**4385**	**456**	**10**
Kenya	14.116	1.687	12	581	90	16
Tanzania	14.302	7.309	51	913	598	66
Uganda	5.370	2.220	41	212	106	50
Rwanda	0.465	0.185	40	25	8	30
Burundi	0.400	0.099	25	27	6	23
East total	**34.653**	**11.500**	**33**	**1758**	**808**	**46**
Zambia	2.600	0.956	37	776	286	37
Zimbabwe	5.450	0.585	11	414	56	14
Angola	3.550	0.603	17	1276	408	32
Mozambique	1.290	0.471	36	828	490	59
Botswana	2.300	0	0	626	5	1
Malawi	0.800	0.033	4	122	6	5
South Africa	14.273	0.150	1	1399	16	1
Namibia	2.070	0.015	1	893	3	0
Southern total	**32.333**	**2.813**	**9**	**6334**	**1270**	**20**
Total	**181.503**	**44.548**	**25**	**23 630**	**9436**	**40**

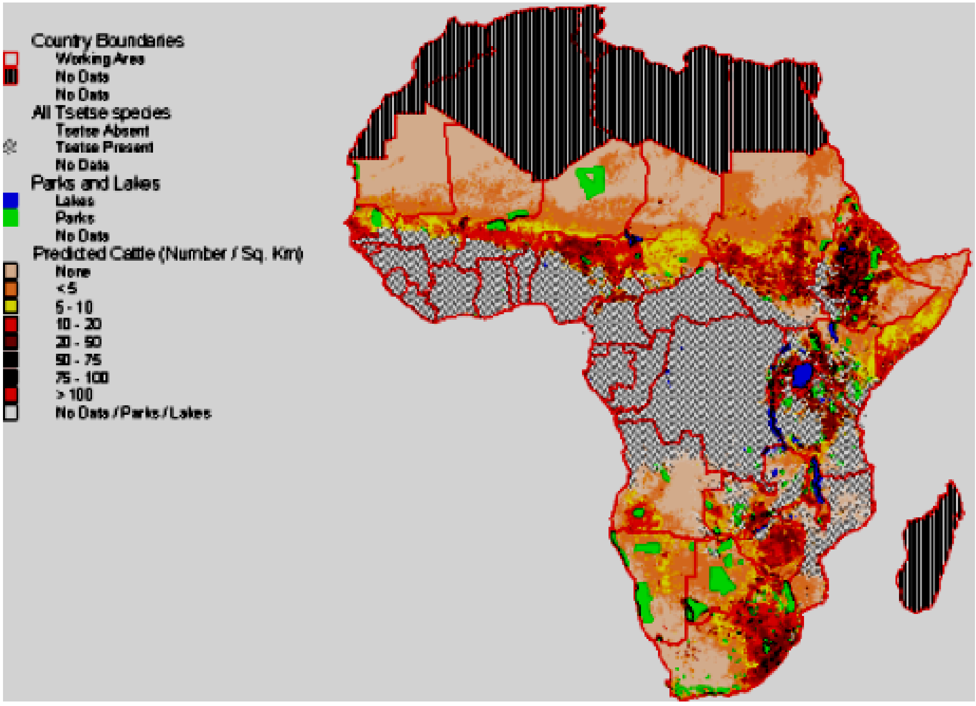


FIG. 4.15 Approximate cattle holdings overlaid with tsetse populations (all species) showing (bovine) cattle at risk.

Dark orange has 100 percent exposure, through brown and yellow to beige with 0 percent exposure. Green areas are parks and blue shows bodies of water.

(Courtesy of W. Wint, Environmental Research Group (ERGO), Oxford University, 2001.)

Recently, substantial progress has been made on the development of standard frameworks for economic cost:benefit analysis of tsetse management on a case-by-case basis, and the standardisation of decision processes (even when conditions of decisions themselves are highly variable) (PAAT 2002). In particular, the incorporation of indirect, extrinsic and partial elements, whether benefits such as animal traction, or costs such as the reduction of benefit if farmers are already using trypanocides, is being addressed by the use of dynamic herd models. Similarly, the high variability of returns between cases in space is being addressed by integration with GIS systems to develop ways in which specific local cases can be assessed individually. Together, these allow herd models to be used for cost:benefit analysis flexibly among different scenarios, with standard components, with emphasis placed on "full costing" and the transparency of the process. Because of the diversity of conditions and their consequences, separate cost:benefit analyses for each individual project or zone have been recommended.

Despite their usefulness, one should take caution if the herd models used to predict possible benefits from removal of the tsetse/tranpanosomosis (T&T) problem still assume that simply additional indigenous, low-productive cattle will be used in the freed areas. It is expected that, with the concurrent development planning and assistance, the creation of any areas free from the pest will be supported in introducing higher productive cross-breeds.

Another complex issue is the ambivalence by many concerned about the conservation and sustainable management of African natural resources if tsetse were eradicated. It is often argued that tsetse flies keep cattle out of areas where the soil and vegetation, currently grazed by wild animals with some immunity, are fragile and prone to the destruction of their productive capacity if overstocked and overgrazed. The scenario emerges in which tsetse control may lead to uncontrolled and unsustainable cattle rearing, with the elimination of wild vegetation and animals and, subsequently, loss of the productive capacity of the vegetation and desertification.

However the situation is never as simple or clear cut as this suggests. Large areas were cleared of tsetse in the Kruger National Park in South Africa in the 1950s and in northern Nigeria in the 1960s.The wildlife have not disappeared from the Kruger Park, and despite earlier estimates of the advance of the Sahara south, the latest estimates indicate that northern Nigeria is no drier or more degraded than in the 1950s despite a substantial increase in the number of cattle in this dry area. In another situation tsetse can directly threaten the environment; in the Lambwe valley in Kenya the Ruma National Park is under pressure due to the presence of tsetse in the park. Previous tsetse control efforts have been reduced allowing the tsetse population to build up to the point where it is now threatening the herds of cattle outside the park. The herd owners are aware of the source of the tsetse, and in the absence of effective tsetse control are deliberately cutting the trees and bush in the park to reduce the available tsetse habitat. A recent proposal to eliminate tsetse from the park is being backed by the Kenya Wildlife Service as the best way to protect the park.

The presence of tsetse and trypanosomosis in the Matusadona game reserve near Lake Kariba in Zimbabwe is assumed to have jeopardised an effort in 1984 to reintroduce the white rhinoceros: eight introduced rhinos did not survive, probably because they had lost their natural immunity to trypanosomosis over many years of captive breeding in tsetse-free areas. In the context of ongoing efforts in southern Africa to open up elephant migration corridors between different game reserves, the fact that this may lead to a reinfestation of the Kruger National Park with tsetse flies and the disease poses a considerable epidemiological threat on the wildlife in the park with serious economic implications.

The tsetse agroecological situation is highly dynamic: in several areas in East and West Africa tsetse are invading existing agricultural areas (e.g. by moving up the escarpments in Ethiopia and Kenya or by invading agricultural irrigation schemes as new habitats caused by humans) and if tsetse are not removed the continuing demand for increased food will lead to increased unimproved cattle herds despite the tsetse, with concomitant impact on the environment. Only with the removal of tsetse may this be avoided, by the intensification of agriculture with improved breeds, ox ploughing, manure for fertilizing land etc.

Studies on the ground have indicated how tsetse control may have differential effects. In southwestern Ethiopia, for example, small ox-ploughed farms, which may be expected to expand into tsetse-cleared areas, have levels of tree cover and diversity similar to those of the wooded grasslands they may be expected to displace. Therefore little ecological disruption will be produced as long as the small and fragmented but densely covered and species rich riparian woodlands may be protected and the incidence of large tractor-ploughed holdings limited (Reid et al. 1997).

Box 4.1 Tourism as a motivator for pest control: potential for tsetse control in Botswana using SAT

The situation in Botswana is fairly unique amongst countries suffering the effects of tsetse flies. Firstly, the distribution of the fly is now limited to a reasonably small area, about 5,000 km^2 (Kghori, 2001) in and around the Okavango Delta due to the historical and current control activities. Secondly, the area has a high value with the tourist industry, in the delta estimated to be worth about US$12 million in 1996 (Kolanyane *et al.*, 2000). In a report in 2000, Kolanyane, Mullins and Nkhori concluded that there is potential for tsetse to cause significant impact to the tourism industry, in addition to the damage to local livestock and humans.

There is currently significant expenditure on fly control, which would indicate a willingness on the part of the government to participate in such a programme. Control was done with aerial spraying of insecticides from 1973 to 1991 but was replaced by using odour-baited targets from 1991 onwards because of concern about the widespread use of insecticides such as endosulfan. In 2001 and 2002 aerial spraying operations (the sequential aerosol technique; SAT) were conducted in the Okavango Delta and it is anticipated that a SIT operation would take care of possible relic fly populations or of invading flies, provided these are detected sufficiently early by routine monitoring activities. The placement of insecticide impregnated targets turned out not to be ideal for the terrain since the delta floods seasonally and targets are difficult to distribute, relocate and service. In addition they also frequently suffer damage from wildlife in the parks. The existing Tsetse Control Division is responsible for the target deployment and servicing but has difficulty maintaining the network over the required large areas. However, the introduction of global positioning systems and geographic information systems has improved the ability to relocate traps. Some of the tour operators contribute to the current control scheme by supplying and placing targets and therefore potentially could contribute to an integrated programme involving a SIT component.

Spraying with Ayres Turbo Thrush aircraft operating out of Gumare
Tsetse News. Tsetse Information Center, Botswana. July 2001. Issue 1.

This relationship between insect vector control and tourism has been seen in other situations. For example, the significant decline in malaria during the 1940s and 1950s was correlated with a massive increase in tourism and investment in Greece, Italy, Portugal and Spain (Crooks and Dyer, 2001).

It would appear that this particular area might be well suited to the adoption of an integrated area-wide approach possibly involving SIT for the complete removal of tsetse fly. Except for the connection to fly populations in Southern Angola and southwest Zambia via the Caprive strip of Namibia, the fly population in the Okavango Delta is isolated, and the mentioned neighbouring countries documented interest in adopting the approach of Botswana to remove the common belt of *G. morsitans centralis* from the sub-region. There is good local expertise and data on the distribution and abundance of the fly that is partially already computerized. The experience with SAT in Botswana should ensure some experienced pilots for pre-release spraying, if required, and the subsequent release of the flies into the region. Although there is no current plan to construct a production facility in Botswana; there are considerations underway to include establish a small scale national SIT capacity as part of a national preparedness strategy, in case areas thar were freed from tsetse flies are reinfested.

It is a national decision as to whether possible loss of wildlife or the loss of potentially productive cattle land is the more serious. There is an inference that tsetse control may do more harm than good if not backed up by range management with adequate policy development to identify, prioritize and address the main policy goals, as well as adequate scientific expertise to develop a sustainable strategy and adequate management capacity to prevent overexploitation. This idea, however, is not supported by the experience in northern Nigeria. Regardless land use planning should be a component of any tsetse and trypanosomosis management project to prevent overstocking. Without this perspective area-wide tsetse control in areas currently devoid of cattle may be expected to meet with political resistance from some wildlife conservationists. It should be realized that land changes brought about by human activity are substantial even in the absence of tsetse control, and are most likely greater than those caused directly by tsetse elimination (Bourn et al. 2001).

4.5.4 Costs and benefits of tsetse eradication

It has been argued that large scale, area-wide control should be expanded as a proper response to a real source of misery. The costs of bringing tsetse under control across Africa have been estimated at US$20 billion, but that the benefit to agriculture would be US$50 billion within ten years (Allsop 2001). These costings assume a stabilization of SIT costs with the establishment of mass rearing facilities at the rate of an estimated US$400/km^2.

In combination with the estimates of areas infested, from Table 4.11, this cost figure allows some estimates of likely costs of SIT components of campaigns of different scales and sizes. Although tsetse damage and therefore returns to management vary widely between areas, the costs of large scale control are relatively constant per unit area. The implications of the effects of scale and of SIT are summarized in a study (Budd 1999) dividing hypothetical control operations into seven scales, as shown in Table 4.12.

Considering the annual expenditure for continuous tsetse control and assuming that the tsetse suppression activities follow the area-wide principle, the complementation of ongoing tsetse/trypanosomosis management activities with a SIT component for tsetse eradication needs an investment over 18 months that equals two to eight years of recurrent expenditures for tsetse control. The market for SIT will clearly depend critically not only on how much tsetse management investment is made, but also of which of these seven scale categories predominates in various places and times.

An added cost is that of adequate surveillance and continuing perimeter defence of any local eradication. This is essential, yet exactly the sort of activity for which it is difficult to maintain the political will after the project has been declared a “success”. It should include risk assessments of reinvasion, along with detailed response plans (including automatic funding mechanisms) for any incursion of the pest into areas declared to be pest free.

The ease of eradication will vary between cases, but in ways not yet understood. The Regional Tsetse and Trypanosomiasis Control Programme (RTTCP) was established with the aim of tsetse elimination in the subregion, but the objectives were progressively altered in response to pressure from European environmental lobbies and finally succeeded in eradicating tsetse from only a few areas of Zimbabwe and not from Mozambique, Malawi or Zambia. As a result of these imposed political constraints, one economic study of its returns concluded that for maximum economic efficiency control was best managed at farm level; without these constraints the conclusion would almost certainly have been different. The role of vegetation management is also unclear. In at least some cases the alteration of habitat by human settlement, particularly the cutting of savannah trees in which *Glossina morsitans* spp. roost, appears to have obtained a permanent disappearance of this species from fully settled areas. Similarly the expansion of cattle herding southward into the sub-humid parts of Nigeria has had an impact. On the other hand, riverine tsetse species may be able to adapt to living in and around human settlements.

Table 4.12 Cost and benefit estimates for tsetse control options over seven different scales,all over 20 years (Source: Budd 1999)

Size Scale (km^2)	**Farm** 1	**Village** 10	**Locality** 100	**District** 1000	**Province** 10 000	**Nation** 100 000	**Region** 1 000 000
Stage 1							
SAT[a]					2 200 000	20 000 000	200 000 000
Ground spraying					700 000	7 000 000	70 000 000
Targets	4 500	30 000	225 000	562 500	600 000	6 000 000	60 000 000
Treated cattle	800	6 400	90 000	300 000	240 000	2 400 000	24 000 000
Barrier establishment					600 000	1 200 000	2 000 000
Stage 2							
Targets				1 012 500			
Treated cattle				420 000			
SIT					*5 000 000*	*40 000 000*	*400 000 000*
Total establishment	**5 300**	**36 400**	**315 000**	**2 295 000**	**9 340 000**	**76 600 000**	**756 000 000**
Maintenance							
Barrier maintenance					9 600 000	19 200 000	32 000 000
Treatment repeats					10 000 000	80 000 000	800 000 000
Total maintenance	**0**	**0**	**0**	**0**	**19 600 000**	**99 200 000**	**832 000 000**
Total operations	**5 300**	**36 400**	**315 000**	**2 295 000**	**28 940 000**	**175 800 000**	**1 588 000 000**
Others							
Monitoring		3 640	31 500	229 500	3 920 000	19 840 000	166 400 000
Management		910	7 620	57 375	723 500	8 790 000	119 100 000
Contingency	265	1 820	15 250	114 750	1 447 000	8 790 000	79 400 000
Total others	**265**	**6 370**	**54 370**	**401 625**	**6 090 500**	**37 420 000**	**364 900 000**
Total	**5 565**	**42 770**	**369 370**	**2 696 625**	**35 030 500**	**213 220 000**	**1 952 900 000**
Total km^2	5 565	4 277	3 693.7	2 696 625	3 503.05	2 132.2	1 952.9
SIT as % of total	*0.0*	*0.0*	*0.0*	*0.0*	*14.3*	*18.8*	*20.5*
SIT km^2	*0*	*0*	*0*	*0*	*500*	*400*	*400*
Cattle km^2	15	10	7.5	5	5	5	5
Gross benefit	13 500	90 000	675 000	4 500 000	50 000 000	500 000 000	5 000 000 000
Gross benefit km^2	13 500	9 000	6 750	4 500	5 000	5 000	5 000
Net benefit km^2	7 935	4 723	3 056.3	1 803.375	1 496.95	2 867.8	3 047.1
Cost/benefit ratio	2.4	2.1	1.8	1.7	1.4	2.3	2.6

[a] SAT=Sequential Aerosol Technique

As the operations increase in scale, the following characteristics become evident:-
1 - increase in role of SIT and other area-wide techniques
2 - decrease in local and individual techniques
3 - increasing shift of responsibility from beneficiaries through communities to states
4 - increasing shift of management from beneficiaries to technical and professional staff
5 - increasing reliance on imported and non-local inputs

Simply because of their greater susceptibility to control, most successful eradications (Zimbabwe, South Africa, Nigeria) have occurred in the margins of tsetse-friendly environments, where conditions were not optimally favourable and fly populations under seasonal stress. The returns to efforts at eradication and even control in the wetter heartlands of central and coastal West Africa are less certain. Success against the *Fusca* group of tsetse, which is more prevalent in these more humid areas (Nagel 1995), has been demonstrated or attempted relatively rarely.

It is increasingly evident the returns to tsetse management are greatest at an intermediate level on a continuum of increasing density of people and cattle per unit area – below a minimum threshold (very loosely 5-10 animals per square kilometre, and not rising) the density of "benefit units" per unit area is too low to generate adequate returns; above a maximum threshold (very loosely 40-70 animals per square kilometre, and rising) the density of cattle falls as cropping and dwellings replace grazing land, and the land use changes of human habitation disfavour tsetse populations (PAAT 2002).

4.5.5 The debate between local based control and area-wide control of tsetse

Arising from the peculiarities of its case, there is some controversy over the most economically effective financial support to tsetse control. The first is the scale and proper level of management of control. The second, connected with it, is the role of SIT. In general the trend over several recent years, connected with wider efforts at structural adjustment of the economies of developing countries, has been to assume that large scale, particularly state-driven efforts will decline, and small scale, community participatory and private sector ones increase. As a result, in general, in recent years eradication campaigns gave way to containment operations. On the other hand, others have argued that this is a theory cycle beginning to turn back, and increasing attention is being given to improving the focus and effectiveness of larger scale area-wide integrated management, and of SIT as a component in this.

It is often argued that the best practical management is offered by micro-level control such as "live baiting" – insecticide treatment of individual cattle so that flies attacking them are killed. This simultaneously protects the individual animal and results in some local control. On-farm suppression by internally funded measures such as live baiting can provide good control. However, this does not lead to success everywhere: Although 5400 cattle in a control area of 428 km² in north-eastern Zimbabwe were treated at two-week intervals with insecticides to prevent a tsetse reinvasion, the area was rapidly reinvaded and serious deterioration of the disease situation was recorded (Warnes, van den Bossche, Shereni et al. 1999, Medical and Veterinary Entomology). Baylis and Stevenson (Parasitology Today, 1998) cite other examples of pour-on operations that encountered substantial difficulties.

One estimate of the costs of area-wide aerial spraying (in Botswana) is of US\$285 km^2 (one-off cost). Costs of "very good" suppression by seasonal trapping were found to be (in Côte d'Ivoire) US\$30 km^2; this is a recurrent annual cost and represents only a fraction of the total cost for control in that case. The real cost ranges between US \$200 and US\$400 km^2.

Some argue that above all tsetse control's dual private-and-public nature allows deployment by herders as a self-interested investment, thereby undercutting problems of free riders, cost recovery and the externality of the benefits of control, so that it can practically obtain control alone. On the other hand, there is no known case where the use of traps deployed by society as a social protection, even where effective, were maintained by individuals when outside funding was withdrawn (Bauer and Snow 1998).

Live baiting has immediate beneficial side effects in the control of ticks and tick-borne diseases, e.g. *Amblyomma variegatum*, a vector of cowdriosis and dermatophilosis in West Africa and of theileriosis in East Africa. But it may also undermine tick control by upsetting animals' natural balance with ticks and their diseases. After tsetse eradication farmers will stop live baiting for tsetse control. If no attention is given to the tick problem ticks may resurge. However, stopping live baiting will enable the implementation of a more strategic control of tick born diseases by only seasonally applying acaricides.

Realistically, restriction to private-level control assumes that small scale methods – essentially live baiting and attractant trapping – are able to provide satisfactory control, so that costs can be fully internalized without compromising production. In fact it seems that these point protection methods cannot always obtain good control, depending on at least some consistency of control deployment over large areas, and an environment not highly favourable to tsetse – for example lacking numerous reinvasion routes, favourable vegetation and alternate hosts, and suitable habitat for the species present (Hargrove et al. 1999). On

Zanzibar intensive live baiting failed to achieve eradication. In particular, live baiting assumes that flies feed little on other hosts than those treatable, but in the Gambia *Glossina morsitans morsitans* was found to take only 2 percent of blood meals from cattle. In Burkina Faso *G. palpalis gambiensis* and *G. tachinoides* take 55-76 percent of blood meals from lizards: the disposition of different species, in different areas, to feed on domestic relative to wild hosts may dictate the effectiveness of live baiting for local control.

Public, sub-region-wide, control is particularly at risk from political unrest if it is not based on area-wide principles. Resurgences of tsetse populations in recent years have generally been in areas disrupted by conflict, such as Rwanda and the Democratic Republic of Congo (ProMED 2001a). The denial of access of monitoring/control personnel to areas on the defensive border between cleared and pest reservoir areas would be particularly serious, as flies could then freely reinvade through such areas.

Area-wide control has manifest advantages. A theoretical study of tsetse reinvasion of cleared areas Hargrove (1999) estimated that (although individual population parameters need to be calculated for specific cases) even with some of the most optimistic assumptions, reinvasion may be rapid. For example with survival of 0.001 percent of the original population in 10 percent of the treated area, reinvasion is complete within two years for a cleared area of 10 000 km^2 and within one year for a cleared area of 100 km^2 – similar to observations in the field in Kenya. These conclusions argue for the maximization of the size of the area to be cleared, and for the complete eradication, rather than suppression even to a small remnant, of the fly population within the cleared area. Also with area-wide elimination, the risk of reinvasion is minimized, allowing control even in politically unstable areas where access may be denied in the future.

The SIT is a potentially important component of integrated disease management (IDM) of trypanosomosis. The case rests on two claims. First, discussed above, is that the ability of tsetse to do damage at low levels argues that local extermination, rather than suppression, is worth the extra effort, and that this should be based on the area-wide concept in order to be sustainable. Second is that SIT can best provide this because of its characteristic, unique among control methods, of becoming more effective, not less, the scarcer the target becomes, which presumes acting on a low population density, probably reduced by other methods (as in the successful Zanzibar eradication).

The SIT is likely necessary for eradication in quite a number of cases. It is unique among controls in that the density-dependence of its suppression is inverse – it operates more strongly against low population densities than against high ones. This gives it unique advantages for finishing off populations already depressed by other controls. Successful eradications have been obtained in the past without SIT, by insecticide sprays and even traps in Zimbabwe, South Africa and (locally) Tanzania, and on Principe in 1905 using the plantation workforce itself as traps, but concerted conventional efforts in Zanzibar failed to achieve eradication until SIT was deployed to eradicate the remnant population. The percentage of cases where it will be required and applicable is open to debate (Molyneux 2001; Hursey 2001).

In spite of some disagreements about the potential for SIT (Molyneux 2001; Hursey 2001), resolution may be possible by strict prioritization of cases where it is likely to be most cost-effective, without having to know at the outset how far down the prioritized list the technology may usefully be used. The SIT, like all tsetse eradication, will not be applied everywhere at once but incrementally, allowing fly production facilities to switch to fresh areas as cleared ones are stabilized. If successful, this will allow initial start-up costs to be defrayed over a long period.

The SIT may be assumed to be required as a component of integrated barrier maintenance as well as eradication, and for standing by for re-eradication of incursions, requiring access to further SIT flies, perhaps in a hurry. Tsetse “frontlines” (expanding fly belts) are thought to move 5-10 km per annum provided the vegetational and climatic patterns are conducive. The SIT interventions in Nigeria, Burkina Faso, and Tanzania were not sustainable largely because of the absence of a larger term sub-regional strategy for area-wide interventions and resulting reinvasion due to deteriorating maintenance. Above all, the sustained maintenance of eradication will require political and administrative determination until the eradication area is expanded to a stage that no neighbouring fly populations are available that could serve as a source of reinfestation.

4.5.6 Funding issues

In spite of recent harmonisation, there appears to be still a difference of emphasis and possibly of vision between that of the official OAU heads of state target, of eventual continental (and therefore global) eradication, and a more prioritized approach, case-by-case and focusing initially on cases offering clear benefits, likely to be favoured by donors and other international agencies. Some observers suspect that the continental eradication objective is politically motivated, over ambitious and unlikely to be realized. Others, however, note that it appears to be technically feasible, and that, unlike greater threats such as AIDS or malaria, the technology is available and even largely proven to be feasible, and so the projected return is more likely to materialize.

The conclusion to this debate may arise from the fundamental compatibility of the two views: eradication – if it is to happen – will need to be a part of a longer term subregional strategy, in incremental steps successively carried out and then protected from reinvasion. It seems suppression measures, such as by live baiting, may serve as both an end in themselves and an indispensable precursor to eradication. In the circumstances a similar course of action may be followed whether or not the final stated objective is continental eradication. In such a scenario, some areas will be identified as early targets for local eradication as either a final or intermediate objective, and SIT will be advisable.

The necessary scale of SIT operations, and the political implications of decisions, imply that political will and commitment will be of paramount importance. Tsetse control attempts over decades have shown that the insect can be controlled effectively, but also that there is a tendency for controls to be relaxed over time, followed by recolonization of cleared areas. (This is also a danger of prioritizing the areas that offer the best chance of larger returns in the short term, perhaps allowing apathy later on the lower return but essential final operations.)

Donors will expect counterpart funds from African governments, which will be a key test of commitment. A plausible demonstration of determination on the part of governments may encourage donors to be forthcoming. PATTEC has so far recorded high government commitment in several countries including Botswana, Burkina Faso and Ethiopia and other countries are anticipated to follow this example. Ethiopia has itself met most of the initial costs of constructing its projected SIT production facility. Botswana has also itself funded a local tsetse-eradication campaign, although the current plan is apparently for sterile flies to be imported, rather than reared locally (see Box 4.1).

Part of the financial needs will be for construction, equipping or upgrading of either a few factories with high levels of transport, or more, smaller, local factories operating over a shorter time-span. (Current facilities are shown in Figure 4.15.) Donors may also ask whether factories can be designed at the outset for a different future use when they are no longer needed, as this could have a major impact on cost (see Section 3 discussion on appraisal). In addition the concept of mobile factory would offer the advantage that they could move along with the stepwise eradication strategy that would assure low transportation cost of sterile flies to the release area.

The European Union gives significant support to animal farming, with increasing recognition of the role played by semi-nomadic animal farmers, at a level of €234 million between 1986 and 2000. The year 2000 saw the closure of the major EU pan-African campaign against cattle plague, and the EU RTTCP, the southern Africa programme to combat tsetse and trypanosomiasis entered its final stage after more than 15 years. 2000 also saw the announcement of the launch of two regional programmes against the most widespread and serious infectious diseases, including trypanosomiasis, together representing a total commitment in excess of €83 million (European Commission 2001).

The EU has been funding Farming in Tsetse Controlled Areas (FITCA) in the East African Region It focused on farmer-participatory management of trypanosomiasis, and specifically farmer-managed technologies, and thus included no subventions to SIT as the objective did not include tsetse eradication, but aimed to assist individual farmers to live with continuous tsetse challenge (EU Uganda Delegation). The EU-funded PACE (Pan-African Programme for the Control of Epizootics) Programme focuses on veterinary management and largely on rinderpest and other non-trypanosomal diseases (IBAR 2006).

A considerable step forward was made with the announcement by international organisations of support for the PATTEC goals of "Eradication". In July 2000 at the meeting in Lomé of African Heads of State and Government the aim of PATTEC was stated as the "ultimate eradication of tsetse flies from the African continent" and the FAO has announced its support of the PATTEC initiative and its goals (IAEA 2002c). There has been disagreement with this objective, primarily because it seems at odds with the principle of focussing intervention into those particular scenarios where it offers the best cost:benefit returns. Consensus has been based on seeing eradication as a long-term political "vision", and implementation as by the identification and prioritisation of high potential cases; similarly, SIT is generally seen as being a technology it is desirable to include in the "toolbox" even though some parties have misgivings about the extent of its utility, particularly in local cost:benefit returns (IAEA 2003g).

In conclusion, although the position of SIT as a key component in ongoing tsetse management projects has been firmly established, donors will probably continue to favour a bit-by-bit approach of incremental investment and confidence. It seems logical for donors to adopt something of a "wait-and-see" policy to see whether or not the current Ethiopian campaign can illustrate whether or not the Zanzibar success was unusual (island location, single species, political and administrative determination) or whether it may be convincingly extended to the mainland. In the meantime, significant steps have been taken in the agreement of FAO and the other two "mandated" UN organisations (IAEA and WHO) to support the stated long-term objectives of the PATTEC initiative, namely to create and expand zones suitable for sustainable agriculture and rural development (SARD) that can be freed of tsetse flies and the trypanosomosis approach. This would occur in a phased, conditional manner along the criteria and guidelines for identifying initial priority intervention areas. Meanwhile the first six countries that managed to obtain from the African Development Bank Group (AfDB) – with the assistance of AU-PATTEC – loans and grants amounting to in total US$80 million for national T&T intervention projects requested international assistance from the UN agencies and increasingly accept and the phased and conditional approach for international (FAO, IAEA and WHO) assistance to T&T projects.

4.5.7 What's next?

African leaders did not wait on donors to lead the way towards tsetse eradication, and the goal of eradication of tsetse across the African continent has been announced as an aim by the AU heads of state. They argued that only eradication provides future security and sustainability, and that the objective is achievable. The support of the FAO and other international agencies for this position seems slightly guarded and provisional, however: at present the objectives of prioritisation and eradication are consistent, as current activities point in both directions, but at some future point, if developments go according to plan, eradication will require operations in lower-priority areas where local economic returns are negative, and opinions may diverge again.

One suggestion has been that PATTEC begin to develop a long-term plan and route map for eradication. This will help to resolve the critical question of the different phases of eradication, particularly in terms of "joining up" the various geographic areas where interventions are to be carried out, and the question of the contrasting the costs of a small number of "factories" with subsequent transport of flies, with those of a larger number of factories for local production. This would require long-term planning, e.g. over a 20 - 30 year timescale or longer, but would be an impressive statement of confidence, and would enhance the appreciation of likely costs and benefits.

Control of the desert locust in the Sahel in the 1980s was undermined by the relaxation of funding and political will once the controls had been effective, as to some extent a victim of its own success, with serious consequences (Kremer 1992). Even in Zanzibar, where reinvasion is considered highly unlikely as it is 30 km from the mainland coast (though occasional monitoring will continue) local cattle breeds are being replaced by others more productive but less trypanotolerant. The costs of inadequate quarantine defences should be considered in the long-term plans.

Cattle mortality or reproductive reduction do not fully capture the losses tsetse may cause to cattle populations. Diseased but live animals suffer productivity losses of up to 50 percent. Further losses are as opportunity costs in the use of trypanotolerant varieties, which are less productive than susceptible ones – as has been seen in the introduction of susceptible strains in Zanzibar since tsetse eradication. This may be an area deserving further studies – the willingness to replace local low productive and less susceptible cattle breeds with more productive but more susceptible breeds and cross breeds will clearly be a function of the perception of the risk of tsetse reestablishment, and so perhaps the benefits will accrue increasingly over time as eradication becomes established in the consciousness of cattle farmers.

The uncertainties about the role of SIT, outlined above, give the impression that further developments will await events. The questions over the application of the Zanzibar success to the mainland will be in large part illuminated by the success of the current eradication attempt in Southwestern Ethiopia with flies reared outside Addis Ababa. Many donors and managers may await some clear outcome from this before making commitments to a wider programme.

In summary the peculiarities of the tsetse case among other SIT cases include:

- biological factors that require a longer lead time and/or more and larger "seed" colonies than for other insect pests;
- difficult economic analysis due to knock-ons such as health and traction losses;
- environmental controversy in the protection of soil and vegetation by tsetse and on the term "eradication";
- importance of institutional and administrative infrastructure, and the need for sustained management - perhaps particularly in cases where many agencies benefit (agriculture, health, land use planning, etc.) and so there may be questions over cost recovery even when a programme is fully publicly-funded;
- ongoing debate about the relative merits of local and area-wide tsetse control.

These issues are unlikely to be resolved from outside the affected countries. The importance given to this pest by the African governments is indicative of what can be done. The test will be if this can be sustained for sufficient time.

4.6 The market for animal pest species (other than tsetse)

The New World Screwworm (*Cochliomyia hominivorax* Coquerel), and Old World Screwworm (*Chrysomya bezziana* Villeneuve) only parasitize living mammals, unlike other species of blowfly, making it one of the most serious livestock pests. The NWS infects most available mammals both wild and domestic. Hundreds of human cases have also been recorded in Central America. All domestic animals and companion species are vulnerable. Substantial losses have been recorded in cattle, sheep, mohair goats and deer (Scruggs, 1978).

The earliest use of SIT was against the New World screwworm (NWS). Based on work by Knipling (described in Knipling 1979), the USDA's Agricultural Research Service (ARS) developed the use of sterile screwworm in the early 1950s. The first SIT large scale field programme was attempted in Curaçao in 1954, leading to the successful eradication of screwworm from that island. Following this initial success, by 1959 screwworm had been eradicated from the southeast USA. Eradication was achieved in Puerto Rico and the British Virgin Islands in 1975. Self-sustaining populations were eliminated from the entire USA by 1966, although there were many outbreaks up until 1982 and some questioned whether full eradication had been achieved at the time of the initial announcement (Klassen, 2000).

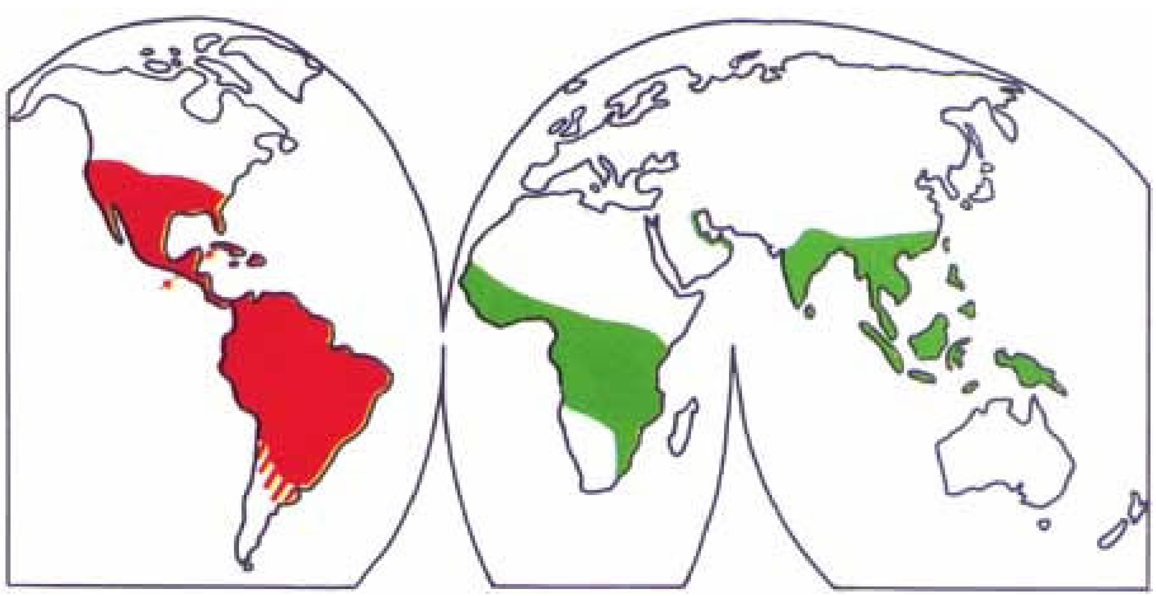


Figure 4.16 Historic distributions of Old World Screwworm (green) and
New World Screwworm (red) prior to eradication of NWS from North America.
Source: FAO, Animal Production and Health Division Web site
http://www.fao.org/waicent/faoinfo/agricult/aga/AGAP/FRG/FEEDback/War/u4220b/u4220b0c.jpg

The only incidence of NWS outside of the Western Hemisphere was an accidental introduction to Libya in northern Africa in 1988, which threatened to spread and become established on that continent. This introduction was eradicated under an intensive SIT campaign in 1991 (OIE, 2000; Box 4.2). These original efforts and all of the large SIT programmes to date are to control the NWS species.

The OWS is a member of another genera of the same subfamily, Chrysomyinae, of the blowflies family Calliphoridae (OIE, 2000). The World Organisation for Animal Health (formerly the Office International des Epizooties or OIE) reviews the latest materials for diagnosis and identification by species of screwworm and comments on control options in its continually revised Manual of Standards and Diagnostic Tests (OIE, 2000). A map of the two current locations for sterile screwworm production appears in Section 5.

4.6.1 New World Screwworm

Distribution of the New World Screwworm

The NWS was found throughout much of South and Central America and throughout the southern USA before eradication took place. On the North American continent its range has included the southwestern states of the USA and across the tropical belt to Florida, as shown in the map above. Natural north-south animal migrations in the USA had led to cases being reported up to the Canadian border (Novy, 1978). Although the NWS was established in the USA for years, it was not considered a severe livestock problem until it first established east of the Mississippi River in 1933. Work on its control was suspended during World War II, but by the 1950s the sterile insect technique had been developed in response to the damage from NWS (IAEA 1999b).

The NWS is present in all countries of South America, except in Chile (Hendrichs, 2001a). Chile has maintained freedom from NWS following eradication, but NWS covers approximately 50 percent of the landmass of the South American continent all year and can move into another 30 percent seasonally (Grant *et al.*, 2000). Some South American countries, including Uruguay and Venezuela, have expressed interest in SIT control due the economic losses they are facing (IAEA 2000b). In response, laboratory populations from Venezuela have been established. Analysis of samples from Brazil and Uruguay, using DNA molecules, showed low levels of population variability (IAEA 2004b; IAEA 2006c).

In the Caribbean region, Jamaica, Haiti, the Dominican Republic, Cuba and Trinidad and Tobago continue to be infested. In fact, approximately 86 percent of landmass in the Caribbean is still infested. This region has over 16 million head of livestock.

The NWS was eradicated from Guatemala, Belize and Honduras by the joint governmental control programme originally launched by the USA and Mexico. Costa Rica was declared free of NWS in 2000, following a similar declaration from Nicaragua in 1997. The USA, Mexico and Central American Governments are close to eliminating NWS from nearly half the continent as a major pest (Hendrichs, 2001a). The IAEA is supporting the project to eliminate NWS from Jamaica (JAM/5/007), discussed below and a small pilot SIT project in Cuba (Hendrichs, 2001a).

Description and Biology

Screwworm flies are about twice the size of a common housefly. Pupation takes place in soil and duration varies from one to eight weeks depending on the soil type, temperature and moisture. Under optimal conditions a generation can take 24 days, but this can be extended to 60-100 days in marginal conditions. The larval period is most constant in duration as this is moderated by the host animal. Adult females oviposit on live mammals, usually at wound sites (a tick bite is sufficient) but also on mucus membranes and in other body orifices; new born animals are especially susceptible. Festering wounds exacerbated by NWS infection attract further gravid females, thus magnifying the problem. The NWS average first batch is around 340 eggs; almost twice as many as the OWS average (OIE, 2000).

Populations vary by season. For example, the population levels were adversely affected by severe winters in the USA prior to eradication. Large diurnal temperature fluctuations are also detrimental to NWS performance (Novy, 1978).

Economic impact and benefit cost analysis for eradication of NWS

The economic impact of NWS alone reaches hundreds of millions of US dollars each year (Vargas-Terán *et al.*, 2005). In addition to the direct losses from infestation and related disease, the cost of labour and insecticides for treating wounds is significant.

It is estimated that the U.S. livestock industry could suffer US$900 million in production losses annually if the NWS were reintroduced (McGraw, 2001). The interest in eliminating NWS from the Caribbean is partially due to the continuing threat of reinvasion to the USA, however this support does not extend to South America (see Section 3.1.1). There are no reliable figures for current costs to eradicate NWS in South America, although one estimate of the benefit should eradication be achieved is US$ 2800 million per year. Because of the lack of natural barriers to the NWS in South America, any attempt to eradicate will require a regional, highly-coordinated approach (Vargas-Terán *et al*., 2005).

Area wide control of NWS by SIT is widely established and supported by both government and livestock organizations. Wide scale eradication of NWS, it has been estimated, will give annual direct benefits to livestock industries that amount to ca. US$800 million for the USA, US$300 million for Mexico and US$80 million for Central America (Hendrichs, 1998).

The economic impact of NWS to Jamaica was examined taking into account increased costs from insecticides and medicine, veterinary services, additional time for monitoring and treating animals, additional labour for the same and loss in value due to animal mortality. Albeit with a wide variation in the data sources, the total losses due to mortality and costs to production were set between US$5.5 million and US$7.8 million annually (Vo, 2000). Benefit cost ratios are all positive, with the full benefits being realized by producers by the end of the second year of an eradication campaign. While there are no wild animals susceptible to NSW in Jamaica, there are companion animals and also the vulnerable public that have suffered from screwworm attack (Grant *et al.*, 2000); the benefits to public health from eradication of NWS are not included in the economic analysis.

A review of the economic losses due to NWS in Cuba concluded that over 97 percent of the costs related to current control is for non-specific medicines, such as antibiotics to treat secondary infections resulting from myiasis. The average cost of control is US$1 for goats, US$9 for cattle and US$23 for pigs. Cost of manpower spent on surveillance and control, however, was more than double for horses than for pigs. Losses surveyed included mortalities, drop in milk production and non-availability of animals for draught, while secondary losses included supplementary feed, transport of samples to laboratory, impact of infection on fertility of animals and in some cases surgery (IAEA 1998a).

The consensus of veterinary experts is that the incidence of NWS is probably under-reported in the majority of countries, with true case often being ten times the number reported officially. Even countries with extensive well-funded and staffed veterinary services may under-report by five fold (see references for IAEA 1998a).

Assuming that cases in Cuba are under-reported five fold, the study found a benefit cost ratio of 5.2:1 for over ten years, with payback in four years. No consideration for eliminating a significant source for reinfestation of neighbouring countries is included in these figures. Besides the two years required for an SIT eradication programme, capital investments to improve on going quarantine will be required. In 1996, the cost of sterile NWS flies was set at US$1700 per million and an estimate of costs for transport of the sterile insects, release, international consultants, Cuban staff, increased surveillance and contingencies was set at nearly US$38 million by an FAO consultant (IAEA 1998a). Table 4.13 shows projected costs from another source and sets the total cost for Cuba much higher, at US$54 million.

The cost for Nicaragua was around US$77 million, however the land borders with the then still-infested Costa Rica added to the expense. Nicaragua is only 14 percent larger than Cuba, so the higher estimate for Cuba would seem realistic (IAEA 1998a). In the eradication of NWS from the Caribbean, it is possible that Trinidad and Tobago will be left for control measures in conjunction with South America due to their close proximity to that landmass (Grant *et al*., 2000).

While any myiasis (injury inflicted by dipterous larvae) should suggest screwworm, the USDA/ARS has developed a field kit to differentiate screwworm maggots from similar species in a matter of hours rather than a couple of days (Skoda, 2001).

Table 4.13 Estimated costs and number of sterile screwworm to eradicate NWS from the Carribean

Country	Sterile NWS required	Cost for entire programme
Jamaica	20 million/week/3 years resulting in 15 million to release	US$9 million
Hispaniola (Dominican Republic and Haiti)	95 million/week/2 years	US$35.55 million
Cuba	150 million/week/2 years	US$54 million
Trinidad and Tobago	8 million/week/2 years	Not available

The Jamaican release was set at 1200 sterile flies per km^2. These are 1997 or 98 estimates for costs. Cost of sterile flies was estimated to be US$1700 per million at the emergence centres.

Source: Grant *et al.*, 2000, except for Trinidad and Tobago which is calculated based on area.

Other factors affecting the cost/benefit of an SIT programme include the actual costs of mass rearing and sterilization of the pest. Recent research aims to develop a genetic sexing strain for NWS, the use of which could reduce the cost of SIT programmes. Development of such a strain could half the costs for sterlization, shipment and release. The permanent barrier of 300 kilometers in Panama, for example, would have an annual budget of US $10 million (IAEA 2002f; IAEA 2006c). Recent reductions in the cost of the diet for mass rearing NWS also has had a dramatic effect on overall costs of eradication. The shift from using meat and honey in the diet to spray-dried eggs with honey or molasses, from whole blood to animal blood cells and by using recycled newspaper rather than gel as a substrate, reduced costs by at least half (Chaudhury 2001; McGraw 2001).

Challenges of expanding SIT control of NWS to new regions

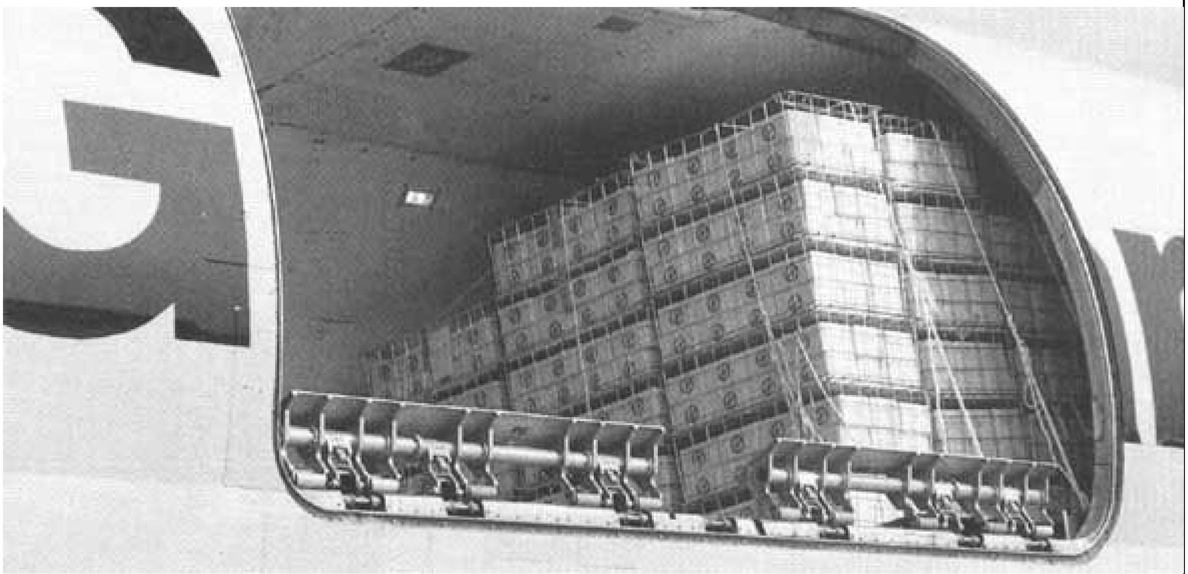
The Jamaican area-wide NWS eradication programme, launched in 1999, uses SIT in combination with other control methods, such as epidemiological surveillance, animal wound treatment with insecticides and quarantine measures. The project has been carried out by the Jamaican Ministry of Agriculture and supported by the United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA-APHIS) and the Agricultural Research Service (USDA-ARS), the Mexico-US Screwworm Commission, FAO and the IAEA (IAEA 2003a). The programme has experienced several setbacks most of which were not related to the SIT technology *per se* (IAEA 2004k).

During the first two years of the project implementation, 20 million sterile pupae, shipped from the Tuxla-Gutiérrez production plant in Mexico, were released weekly from aircraft over the entire island at a density of 3000 insects per square mile. Limited baseline data existed, mostly from studies undertaken in the 1980s, so that the protocols such as release density were simply taken from the Central American programme and applied in this new environment (Vreysen *et al.* 2007). This was found to be a mistaken assumption. At that time, field monitoring and animal wound treatment relied almost entirely on farmers and private veterinarians (IAEA 2003a), furthermore the impact of feral dog infection was underestimated (Vreysen *et al.* 2007) so that in fact, densities were much higher than in the previous campaigns and there were definite hot spots with even greater density of pests. The number of sterile pupae released increased from 20 million to 30 million in January 2002 and to 36 million in April 2002 to enhance the efficiency of the project.

Box 4.2 The eradication of NWS from Libya.

The only incidence of New World Screwworm (NWS) outside of the Americas was when an outbreak occurred in the Libyan Arab Jamahiriya in early 1988. The NWS was presumably carried in on sheep imported from South America. By 1990, the infestation had spread to 25,000 km^2 of Libya and 12,000 infested animals were reported. There was great concern over spread to the surrounding region. Although not native to Africa, the NWS is so closely similar to Old World Screwworm (OWS) in its ecology that it was likely to become an additional serious pest and enter regions free of OWS at that time.

In early 1991 an emergency SIT programme began, supported internationally and coordinated by FAO. This programme was supported by 22 countries and international agencies, particularly IAEA, IFAD and UNDP.



Loading boxes of sterile screwworm for air transport from Mexico to Libya.
Source: FAO, Animal Health.

The NSW sterile fly plant in Mexico supplied 40 million pupae per week for emergence and release in the infested African country. A total of 1.3 billion sterile NWS were shipped by the end of the eradication campaign. The programme included massive efforts of 40 million inspections and laboratory checks of 280,000 trapped flies.

While the total cost of the successful campaign reached close to US$75 million, the benefit cost ratio was calculated at 50:1. Due to improved monitoring, there has been no additional infestation by NWS outside of the Western Hemisphere since this incident.

Source: IAEA, 1999a.

In July 2004, an independent team of experts, requested to review the Jamaican programme, suggested the establishment of a better management structure and improved field supervision to ensure a more efficient implementation of the entire programme and of its field component (IAEA 2004k). Improvements were also recommended in the quality of the released sterile insects, because the original supplies were based entirely on the needs of the ongoing programme aimed at Central American strains. With the use of Jamaican wild sources and new filter colonies, field performance has been enhanced (Vreysen *et al* 2007).

Despite the great success of SIT as a tool for eradication of NWS, this experience showed that using the approach as an existing "off the shelf" technology without the proper preparation, adaptation and data for the local situation will lessen the efficiency of the control programme, ultimately causing higher costs than a more expensive programme run for a shorter time frame (Vreysen *et al.* 2007). At this time, SIT, although not a stand alone technique, is the principal form of control used on a large scale against NWS. The major direct saving accrued by the use of area-wide SIT lies in reducing the labour costs associated with close supervision of ranged cattle.

4.6.2 Old World screwworm

The Old World screwworm, *Chrysomya bezziana* Villeneuve (Diptera, Calliphoridae) is a separate species from the NWS but an ecological equivalent; the two species have markedly similar biological characteristics and behaviour, but their ranges do not currently overlap.

Hosts

The OWS infects most available mammals both wild and domestic. Hosts include cattle, water buffalo, camels, sheep, goats and even elephants. Human cases have also been recorded. All domestic animals and companion species are vulnerable, although the greatest losses have been recorded in cattle and sheep (Animal Health Australia 2001).

Distribution of the Old World screwworm

As shown in Figure 4.16, the OWS is found throughout much of Africa. Its African range runs from the southern Sahara to northern South Africa, with some reports in Algeria. It is also present in India, throughout Southeast Asia and in Papua New Guinea. The OWS has never been established in Australia, but it has been detected and controlled. Computer modelling has shown that if an entry occurred without detection, the OWS could cover most of northern Australia year round and extend into southern Australia with milder temperatures. Most likely entry points are the Torres Strait, Cape York Peninsula and, to a lesser degree, the Northern Territory (Animal Health Australia 2001).

An outbreak of OWS occurred in Iraq in 1996, but reports and a contemporary survey showed that the pest was already in Iran, Kuwait, Oman, Saudi Arabia, the United Arab Emirates and Iraq itself prior to this surge in population. The OWS is a relatively recent introduction into the Middle East, however, possibly arriving in the past 25 years. Genetic analysis suggests that these introductions came from Sub Saharan strains, which in turn are linked with Asia. Introductions may have occurred from in-transit infestation of livestock shipments from Asia (IAEA/TCPCS 2001).

Research on population genetics of OWS samples, using isozymes, mitochondrial DNA and a nuclear gene, revealed insignificant genetic differentiation over the entire geographic range of this species, which is favourable to future SIT programmes. The OWS samples were obtained from Indonesia, the Islamic Republic of Iran and Oman (IAEA 2004b; IAEA 2006c).

Description and biology
The average first batch has around 175 eggs; further batches are laid every three to four days. Adults live two to three weeks under field conditions (OIE 2000). The eggs hatch after 18-24 hours and the larvae burrow deep into the flesh of the host whilst passing through 3 instars. The larval period lasts a total of five to six days after which the larvae exit the wound and move to the ground for pupation. The duration of pupation depends on the temperature regime of the area in question and can last from one to eight weeks.

Adults are able to travel long distances, therefore any attempt to control must cover a sufficiently large area. Adult females will fly 25-50 km in order to find suitable host animals. In fact, travel of up to 300 km has been recorded (OPEC 1999) but long-distance dispersal is usually associated with movement of infected animals.

The OWS is very temperature sensitive and will not fly or mate below 16°C. Its optimal temperature range is 20-30°C. Temperature tolerance is a major factor in distribution. For example, while the pest is prevalent throughout Papua New Guinea, it does not occur above 2500 m in altitude there (Animal Health Australia 2001). Pupation is not possible where the soil is either waterlogged or overly dry.

Damage from OWS
If OWS infests an unprotected animal, it can cause death in a matter of days (OPEC 2002). However, it is considered to be less damaging than NWS. One explanation for that is the overlap of OWS with tsetse; in zones with tsetse there has been less exploitation of livestock and therefore possibly less opportunity for damage from OWS (A. Parker, pers. comm., 2001). Another possibility is that the damage simply is not well documented in economic terms in the infested regions because there have not been large control programmes in the past that would justify this research.

In Southeast Asia, cattle and buffalo owned by smallholders are closely managed so that infestations are controlled. In a heavily infested herd, OWS may strike 10 to 15 percent at the same time. In new-born calves mortality can reach 30-50 percent from navel strike if not controlled (Animal Health Australia 2001).

During the outbreak in Iraq, OWS was first recorded in August 1996 and by April 1998, there were 60 000 cases of OWS in livestock and 19 in humans. The break down of the veterinary services prior to this event would suggest that these cases are under-recorded. The severe drought of 1998-99 was credited with preventing the further spread of OWS (IAEA/TCPCS 2001). Future outbreaks in this region may easily occur without an active control programme.

Current control
Treatment of an infested animal requires application of organophosphorous insecticides, such as coumaphos, dicholfenthion and fenchlorphose. These are also used to treat wounds to prevent infestation (OIE 2000). Such treatments directly control the screwworms, but also other external parasites such as ticks that are often the cause of wounds that give opportunity to more infestation. In parts of Africa dipping of cattle to control ticks has reduced the incidence of OWS. Alternative control and population suppression methods currently used include resistant native stock breeds and direct wound treatment for myiasis with pesticide (only practical in small, well supervised herds).

Control of OWS in Asia and Australia
The situation with the OWS is distinct from the NWS in so far as the potential sources for funding. While the economic benefit to Australian industry from preventing an introduction is

well documented, there are many countries in which the impact of OWS is greatest to the poor or to low resource or unorganized livestock industries.

The Governments of Australia and of Malaysia ran a joint programme from 1995 to 2000 to validate the use of SIT as effective against the OWS, determine the best approach for mass rearing and sterlization of OWS and develop expertise within the Department of Veterinary Services (DVS) Malaysia to manage and operate an OWS sterile insect production facility (Vargas-Terán *et al*. 2005). During field trials, the production was released at 500 male per km^2 in infested areas until 60 percent of captured screwworm flies were infertile, at which point the trail was declared a success (Institut Haiwan 2002).

The Government of Australia allocated AUD$3.6 million for the design, construction and equipping of a facility with capacity to produce 10 million sterile screwworm (both sexes) per week. An additional AUD$2.275 billion was allocated for operating costs, maintenance and training (Institut Haiwan 2002). The Government of Malaysia provided the sites for the buildings, personnel and support for the initial field trials. The entire facility reverted to DVS Malaysia ownership upon conclusion of these trials. Their ultimate goal is to eradicate OWS from Malaysia.

Vargas-Terán *et al*. (2005) reports on the Australian policy to construct a facility if an emergency control programme is required. A design has been prepared for a facility with capacity to produce 250 million sterile screwworms per week. Although studies show the advantages to constructing such a facility before an incursion occurs and control is required, the high costs have delayed any action on that score. Such a facility could be used to produce other sterile insects, such as Qfly or Australian blowfly for suppression programmes until the facility is required to control an exotic pest.

Inspection of animals in trade, quarantine and surveillance are also important aspects of prevention (OIE 2000). In Australia an enhanced surveillance program using 'swormlure' a specific attractant is in place in the Northern Territory since livestock is not closely managed there. Adult flies maintain relatively low numbers naturally so that field observation of OWS outside of the larval stage is not likely (Animal Health Australia, 2001).

A description of all the preparation that would be required before developing a control programme throughout SE Asia is described by Vargas-Terán *et al*. (2005).

Control of OWS in the Middle East

The first phase of the OWS control in the Middle East was based on emergency use of insecticides by spraying and dipping along with sticky traps for monitoring. Research on the ecology and movement of the OWS in the Middle East supported this phase (OPEC 2002).

The FAO coordinated an eradication program for OWS in Kuwait in 1998 using insecticides and quarantine. This approach to eradication is not effective for more than a small incursion, however. Phase two of the Middle East control programme will integrate SIT, based on the success of the eradication of the NWS in the USA, Mexico and North Africa (OPEC 2002). The programme will continue under coordination among FAO, IAEA and Arab Organization for Agricultural Development (AOAD) (FAO/ALAWUC 2002).

The eradication campaign in the Middle East has received support from the Organization of Petroleum Exporting Countries (OPEC) Fund for International Development. This support is channeled through the AOAD and runs through 2004 and has totaled US$750 000 (OPEC 1999; OPEC 2000). Technical support has been provided by FAO, IAEA and the

International Fund for Agricultural Development (IFAD). Additional funding has come from the Arab Fund for Economic and Social Development, the Islamic Development Bank and a number of other sources.

The situation in the Middle East is different from Asia, where the OWS is long established and wide spread. Eradication is the ultimate goal and this will require construction of a sterile insect facility in that region in the near future. Specific plans for location, size and financing of this facility are not yet announced, but it is expected to be an important component in the on-going campaign organized by the AOAD. With the inclusion of SIT in the control tactics, the OWS may be eradicated from the Middle East within five years (OPEC 2002).

In the short term, the AOAD/FAO/IAEA (2001) reviewed feasibility of creating OWS fly free zones in parts of the Middle East. The results of these efforts will further clarify the possibility of achieving eradication of OWS from the region. Technical skills developed for pest free areas will be needed in continuing prevention of re-invasion and for eradication if that goal is supported.

Iraq has a colony of OWS since 1996 but no mass rearing has yet been started (W. Enkerlin, pers.comm., 2002). This colony is used for research on dose of irradiation and base line field work; sterile OWS may need to be shipped from the Malaysia facility to Middle East sites for initial field trials before a facility could be constructed in the region. At the appropriate stages, IAEA support may also include contracting for purchase and aerial release of sterile screwworm, participation in consultation with stakeholders, donors and other critical organizations, and overall SIT expertise (IAEA/TCPCS 2000). These contributions will help in determining the feasibility of eradication from the region incorporating SIT and the need for and location of a sterile OWS production facility.

At the International Conference on OWS control in the Middle East of 2001, the participants recommended the AOAD should intensify its efforts for the control, and the eventual eradication of the OWS in the region. In the participants' view, the strengthening of the OWS rearing activities in Iraq, the support of international institutions and training and research activities were essential for the promotion of the OWS eradication (IAEA 2001f).

Economic impact and benefit cost analysis for eradication of OWS

The estimated herd in the Middle East is 272.5 million head of livestock, worth US$18 billion. Many countries in the region have invested both public and private funds towards making livestock an important sector in their economies (OPEC 2002). FAO figures from 2000 projected the revenue from livestock production in the Near East as equivalent to 30 percent of the gross value of agricultural output for the region (FAO/ALAWUC 2002).

Data regarding the losses from OWS in Malaysia, where a sterile OWS production facility is in operation, are sparse. A 1997 estimate by the DVS Malaysia set losses at US$6 million per year. In a subsequent survey it was found that most infestations are treated by farmers and not reported to the DVS. Costs of treatment ranged from an estimated US$4 per goat to US$7.80 per dairy cow. Mortality was approximately 10 to 20 percent in goats and sheep, 7 percent in buffalo, to a low of 1 percent of dairy cattle. Other losses reported included the need for additional feed, loss of value of animals, loss in milk production, and the indirect cost of time spent checking for maggot wounds and treating them (Grindle *et al.* 2000).

The results of the survey described above were used to carry out a benefit cost analysis for eradication of OWS from peninsular Malaysia focusing on farm livestock, excluding pigs and poultry, simulated benefits over a 20 year period with a standard discount rate of 10 percent.

The investment required to complete eradication was only justified with a benefit cost ratio of 1.78 if the sector were to grow in accordance with the growth plans; historic sectorial growth did not justify the eradication. Another scenario was with improvements to the production of sterile screwworm. With a predicted reduction in sterile fly costs of 40 percent, based on existing knowledge and technologies, the total eradication cost was reduced by 30 percent and the benefit cost ratio rose to 2.54 with sectorial growth with a payback in eight years. This scenario is also viable if the sector growth follows historic trends (Grindle *et al.* 2000).

More detailed economic impact information is available from Australian sources. The only viable approach for control in the case of an invasion and establishment in Australia is eradication including use of SIT (Anaman *et al*. 1994a). In a benefit cost analysis of SIT in the event of introduction of OWS to Australia, 1991 agricultural data was used to show the direct losses for the beef, dairy and sheep industries in relation to the projected costs of various sterile insect production facility sizes. Anaman *et al.* (1994a) demonstrated at that time that the optimal size factory would have a production capacity of 200 to 250 million sterile flies per week. With the worst case scenario for entry and establishment, the benefit cost ratio of eradication with SIT from this emergency production facility was 7.5. When indirect effects on consumers and producers are included, the ratio rose another 80 percent (13.9).

A contemporary study (Anaman *et al.*, 1994b) indicated that the least cost strategy for preparing for OWS invasion would be to build a multiuse sterile insect production facility that could be adapted for other species in the case of eradication needs, as suggested above. Around half of this facility would be devoted to OWS production, with seeding from an overseas colony of OWS maintained continually. This supported the decision to develop a joint venture with Malaysia in the construction and operation of the sterile insect facility there. Over the course of some years, from 1973 to 1991, Australian entomologists developed procedures for mass rearing OWS in a facility in Papua New Guinea. For many years, this facility provided the backup for an emergency response programme if an incursion into Australia had occurred. The capacity of the plant was found to be too limited to adequately serve this purpose, however, and new advances in technology lead to the closure of the Papua New Guinea plan in 1991 (Mahon and Ahmad 2000).

Old World Screwworm (OWS) is mass produced at the Institut Haiwan Kluang, Johor, Malaysia. A description of the design and operation is provided by Mahon and Ahmad (2000). The strain is local and the facility has been operating at capacity since 1999. Although the plant was designed for a capacity of 10 million, weekly production is approximately 6 million insects per week (male and female), using a dose of 40 Gy for sterilization. This production was used for field trials to test the feasibility of SIT against OWS and will provide support to any Australian programme in the event of an introduction to their territories. The Ministry of Agriculture of Malaysia anticipates their facility will be a resource centre for other countries in the region seeking to control OWS using SIT (Institut Haiwan 2002).

4.6.3 SIT control of other species of animal pests or disease

Some other species of insects that cause or are vectors of animal disease may also be candidates for SIT. A review of options for prevention and control of the bot or torsalo fly (*Dermatobia hominis*) took place at a technical meeting in Panama in 2001. The experts highlighted the fact that the traditional chemical controls are not adequate because of the large reserve of alternative hosts (often wild life) and the large number of species that vector bot fly eggs to the cattle, where the larva cause the damage. Further, the extensive scale of many livestock systems reduces the effectiveness of chemical applications (Moya, 2001b). The fact that adult bot fly does not directly harm livestock or humans is a point in favour of SIT for the parasite's control, since release of sterile botfly will not lead to additional damage in the short term.

Reforestation programmes in Argentina and Uruguay have been shown to increase the incidence of bot fly, as the boreal environment favours the insect and practically all forest animals serve as a reserviour for livestock infestations (Moya 2001a). Economic losses amount to an estimated US$260 million per year for Latin America due to reduction in milk production and loss of value of hides (Moya 2001a). Severe infestation can be lethal.

Research is still needed on the key criteria leading to successful application of SIT to bot fly control. Adding this approach to the integrated control of bot fly is an opportunity for future use of SIT that is expected to yield good results.

4.7 The market for SIT control of vectors of human disease

The United Nations General Assembly prepared a statement of their vision of the world over the next years for the UN Millennium Declaration. Among the objectives for 2015 is to halt and begin to reverse the spread of HIV/AIDS, malaria and other important diseases (UNDP, 2001). Besides malaria, reference to sleeping sickness and river blindness also highlighted the importance of controlling human disease transmitted by arthropods.

Table 4.14 shows human deaths and years lost to disability, by trypanosomiasis (sleeping sickness) and other diseases, in thousands per year (Budd 1999). Although infectious diseases are still very significant in terms of death and disability, particularly the human immunodeficiency virus (HIV), insect vectored diseases (see Table 4.15) account for over one million deaths each year and about 35 million years lost from disability and death.

Most serious among these vectors are mosquitoes. Mosquitoes can transmit certain viruses (e.g. dengue, St; Louis encephalitis, West Nile virus), protozoans and filariae (small worms) to humans and both wild and domesticated animals (e.g. USDA/ARS 2001). Mosquitoes serve as vectors for some of the most devastating human diseases in the world. They are also vectors for some emerging diseases that are not yet well understood. Dengue fever, for example, is the most widespread of arthropod-transmitted human diseases. 50 to 100 million cases of dengue hemorrhagic fever occur annually. The only effective control of dengue is mosquito control (USDA/ARS 2001). The primary insect transmitting dengue and yellow fever is *Aedes aegypti*. Malaria is transmitting primarily by *Anopheles gambiae*. Control of mosquitoes using pesticides spraying has been recognized as a serious environmental threat for decades, but the need to protect the human population often rightly takes precedence.

Alternatives for mosquito control are available for small areas (i.e. screening especially for sleeping areas; trapping using an attractant, USDA/ARS 1999) or for individuals (i.e. repellents). Some of the mosquito-borne diseases have medical prophylatics or remedies for treating the disease after transmitted. Effective vaccines against malaria have not been developed as quickly as was originally anticipated and is now not expected to be available until after 2011 (IAEA 2001d).

Table 4.14 Annual deaths and loss of human life years caused by various diseases
DALYs (Disability-Adjusted Loss Years, lost through death and disability)

Disease	Deaths[a]	DALYs[b]
HIV	248 000	18 360 000
Diarrheal diseases	2 866 000	30 350 000
Other infectious[c]	490 000	7 140 000
Sleeping sickness	55 000	1 780 000
Malaria	926 000	30 510 000
Other parasitic[d]	145 000	4 520 000
Total	**4 730 000**	**92 660 000**

Notes:
[a] 1990, all developing countries
[b] 1993, sub-Saharan Africa
[c] Syphilis, meningitis, hepatitis
[d] Leishmaniasis, schistosomiasis, Chagas' disease, onchocerciasis

Source: (Budd 1999).

4.7.1 SIT control of mosquitoes

Experts have identified examples of locations where SIT may be effective against insect vectors of human diseases. These include (as reported by C. Curtis in IAEA 2001d):

- Singapore and nearby parts of Malaysia can use SIT for routine control or to eradicate *Aedes aegypti* and *Aedes albipictus*, vectors of dengue.
- India's urban pockets of *Anopheles stephensi* which are vectors of malaria may be controlled by SIT over small concentrated areas; this would replace heavy use of pesticides.
- Italy and Albania now have endemic populations of *Aedes albopictus* which are potential vectors of dengue.
- The vector for yellow fever, *Aedes aegypti*, was eradicated in most of the Americas (but not in the USA) in the 1950s. Any efforts to repeat this success in response to the rising level of dengue throughout the hemisphere may rely on SIT, given the opposition to use of DDT. Cuba is the only country that has maintained effective control using pesticides.

Field trials of SIT to control mosquitoes have been conducted, mainly in the 1970s. The largest of these trials took place in El Salvador, Burma and India. There were some failures in mass rearing and difficulties with mating behaviour in the field. It may be possible to improve on these trials given today's advances in genetics and mass rearing technology (as reported by M. Benedict in IAEA 2001d). Future field programmes will include SIT as one component of an integrated approach. Improvements in mass rearing, sterilization, genetically-linked sexing traits, and field evaluation are necessary to make SIT an appropriate tool against mosquitoes and the diseases they can transmit. At that time, the group of experts recommended that SIT control or eradication of *Anopheles arabiensis*, an efficient vector for malaria in East Africa and the Red Sea coast, be evaluated in more detail (IAEA 2001d).

Table 4.15 Insect/Arachnid vectors of human diseases

Vector (s)	Disease (s)	Number of humans affected (globally)	Control measures
Mosquito: Family: Culicidae Subfamilies: Anophelinae Culicinae(1)	Malaria, Dengue fever, Elephantiasis, Encephalitis, Yellow fever(1)	350-500 million (approx), 50 million, 120 million, 30-50 000/year (15), 200 000/year (9).	Mostly drugs after infection. Preventive uses of insecticides/ repellents, bed nets- physical barriers, environmental management etc. (3)
Blackflies: (5) Family: Simuliidae	**River blindness** (Onchoceriasis)	18 million (West Africa)	Larvae destroyed through insecticide use
Sandflies: (7) Family: Psychodidae	**Leishmaniasis**: Cutaneous (90%)	12 million (Worldwide)	Insecticide use and disease treatment.
Tsetse fly: (8) Family Glossinidae	**Sleeping sickness**: trypanosomiasis	300-500 000 (est) (Sub-saharan africa)	Control of tsetse (see Chap 4.5), disease treatment.
Triatomines: *Triatoma infestans, Rhodnius prolixu, Panstrogylus megistus (2, 6)*	**Chagas disease** (*Trypanosoma cruzi*)	16-18 million (Central and South America)	Insecticide spraying (12), insecticidal paints, fumigant canisters, housing improvement and health education. More recently an area-wide vector control program.
Deer flies: *Chrysops* (2)	**Eye worm** *Loa loa* (filarial human parasite)	N/A (West and Central Africa)	Traps (11), insecticides etc.
Soft ticks: (tampans) Family: Argasidae (2)	*Babesia* and *Borrelia*	500/year (1995, 16), N/A (rare occurrence in humans)	Livestock dipping, aracides. (13)
Hard ticks: Family: Ixodidae	**Lyme disease** (14), **Ehrlichiosis** (15),	21 273/year (15), 600/year (15),	Avoidance, repellents and vaccines.

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In 2004 a programme was initiated at the Entomology Unit of the IAEA Laboratories in Seibersdorf, to develop SIT for *An. arabiensis*, involving laboratory research on mass rearing, sterilization and genetic sexing as well as field activities in Sudan, and La Reunion. These research activities are a component of the 2005-2010 Coordinated Research Project for control of male mosquitoes, which will also focus on aspects of aquaculture and aquatic microbiology (IAEA 2005b). More information on the rearing process is reported in Section 5.

Studies on the three colonies of *An. arabiensis* from three field populations showed that individual oviposition behaviour (e.g. per cent eggs oviposited when tubed) and the hatch rate of individual batches of eggs varied considerably (IAEA 2006e).

Field studies of *An. arabiensis* are carried out in selected areas by the Nile in the provinces of Dongola and Merowe in Northern State of Sudan. The project is a joint venture of the IAEA and the Government of Sudan and is supported by the Sudanese Tropical Medicine Research Centre (TMRI) and UK experts. Automated climate data are collected and monthly surveillance of larval and adult populations is carried out to create a database on the locality and type of breeding sites as well as on mosquito breeding, species and density. In addition, the TMRI has established mosquito colonies from both provinces for research purposes (IAEA 2004i; IAEA 2004*l*). A similar research project for the Reunion was launched in 2005. In addition to studies on mosquito abundance, distribution and genetics, the project focuses on the evaluation of trapping methods and ecological and socio-economic impact studies (IAEA 2005b).

Such initial studies are required to prepare for the eventual field evaluation of the SIT technology for *An. arabiensis* and the potential elimination of this species from the selected areas.

Research on germline transformation using injections of *piggyBac*/3xP3-EGFP demonstrated that the use of this technique resulted in consistent hatch rates, ranging from 8 to 14 per cent, and in transient transgene (GFP) expression in injected G0 (original generation) larvae. Currently, research seeks to improve the mating efficiency of mosquitoes maintained as small families, thereby increasing the chances of recovering sufficient numbers of G1 (first generation after transformation) transgenic insects. It also focuses on developing appropriate methods to conduct excision and transposition assays and to confirm the functionality of *piggybac*-based germline transformation in *An. arabiensis* (IAEA 2005f).

A review of the major human diseases clarifies why only some of these can be controlled using SIT. Most obviously, only those diseases with insect vectors can be considered for SIT. The characteristics of a species necessary for successful SIT are outlined in Section 4.1.

4.7.2 Tsetse as a vector for human disease

The tsetse fly, the vector of African trypanosomiasis or sleeping sickness, has already been controlled by SIT, as is highlighted in Section 4.6. The International Scientific Council for Trypanosomiasis Research and Control confirm other reports indicating a re-emergence of trypanosomiasis in Africa. There has been an alarming upsurge of sleeping sickness in Uganda and several other East and Central African countries. The Council, which is an organ of the OAU, reported that the infection rate has reached the devastating peak of the 1930s in Uganda, Sudan, the Democratic Republic of Congo and Angola (ProMED 2001a).

Sleeping sickness remains a serious health problem for Africa, in general, and for some African countries, in particular. An African Union report, published in 2003, reveals that the disease has threatened development throughout the continent, with more than 500 000 infected people, 80 per cent of whom die (ProMED 2004c). In addition, the WHO estimates that, currently, between 300 000 and 500 000 people suffer from sleeping sickness and that, in some provinces of Angola, the Democratic Republic of Congo and Sudan, the rate of infection is between 20 and 50 per cent (ProMED 2005b). Similar figures were quoted by Teofilo Josenando, Director of the national Institute for Combat and Control of Trypanosomiasis (ICCT), in Angola. In seven provinces, 800 000 people out of the 4 million at risk are infected yearly. These provinces are Bengo, Kuanza-Norte, Kuanza-Sul, Malanje, Uije, Zaire and Luanda provinces (ProMED 2002). The spread of the disease in rich in mineral resources Angolan regions, i.e., the oil-producing Zaire and the diamond-bearing Malanje, had economic implications, according to Ndinga Dieyi Dituvanga, an ICCT official (ProMED 2004c). In addition, Mary Mugenyi, the Ugandan Minister of State for Animal Industry, was reported as saying that 5.1 million people were at risk after the spread of tsetse flies to about 70 per cent of Uganda, including formerly disease-free areas, such as Kumi, Soroti and Kaberamaido, in 2003 (ProMED 2003b)

Although not as serious as in the countries mentioned above, the disease also has re-emerged in Togo, Benin, Congo, Cote d'Ivoire, Ghana, Gabon and Malawi. Christopher Kwame Doku, Deputy Director at Ghana's Veterinary Services Department, was quoted as saying the disease could only be controlled “through massive spraying with designated drugs most of which are toxic and expensive.” He projected that it would take at least the next 20 years to spray Ghana's total infested area at a cost of at least US$30 per km^2 of an infested area (ProMED 2001b).

Civil unrest and wars in Central Africa have made surveillance and reporting almost impossible. According to a commentary, reported cases of the disease in recent years are from countries where surveillance coverage is about 5 per cent (ProMED 2005b). Reports from Medicins sans Frontieres show that trypanosomiasis in the Democratic Republic of Congo by year 2000 had reached levels higher than in the 1920s, when control measures began (ProMED 2001c). Other evidence has been the increasing number of tourists returning from East Africa with trypanosomiasis, as reported through TropMedEurope.

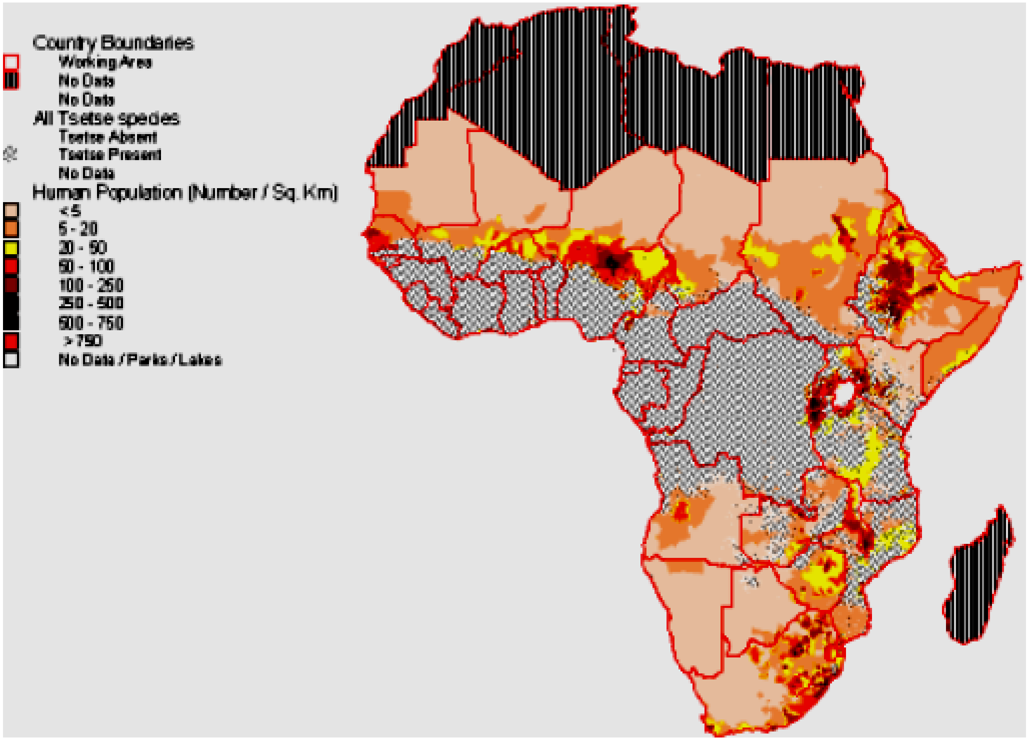

Figure 4.17 Estimated human population overlaid with predicted tsetse populations (all species). Ranging from less than five people per km^2 to over 750 people per km^2.
(Courtesy of W. Wint, Environmental Research Group (ERGO), Oxford University, 2001)

Sleeping sickness in animals, or nagana, has re-emerged in sub-Saharan Africa. The Kenya Trypanosomosis Research Institute (KETRI) conducted a survey in March, 2001 and found that 31 out of 764 animals sampled in 8 representative areas had been infected, translating to about 4 per cent infection rate. The sampled areas were Kamato, God Jope, Nyadenda, Magunga, Olando, Ndisi, Ombek and Andingo (ProMED 2001d). In Uganda, 40 per cent of cattle were infected, according to a report, due to the spread of tsetse flies (ProMED 2003a). In addition, FAO estimates that the disease threatens about 50 million cattle, affects the productivity of infected animals and causes about 3 million deaths in cattle per year. These estimates suggest the economic consequences of the disease for agriculture. They also give rise to concerns about further spread of the disease in humans (ProMED 2004c).

There is no indication of new strains of tsetse. Experts agree that unsustainable control measures in the past and the disruption of political unrest, which brought about the breakdwn of these measures, is the cause for recent increases in the incidence of the disease. The Council issued a statement saying "the strong incidence of trypanosomiasis highlights the failure of former methods and the urgent need to elaborate efficient methods." In fact, tsetse has been controlled down to 99 percent by 1991 in Kenya but has since risen to higher populations (ProMED 2001d). In addition, the return of displaced people, following peace agreements, has also contributed to the upsurge of the disease in some countries, such as Angola and Uganda (ProMED 2002; ProMED 2004a; ProMED 2005d).

Sleeping sickness control relies mainly on systematic surveillance of at-risk population and concurrent disease identification and treatment of infected people. Surveillance and identification are difficult to achieve due to limited resources, lack of infrastructure and low, or non-existent, awarenesss of the disease among health workers and the community (ProMED 2003a; ProMED 2004b; ProMED 2005a). As Dr Victor Kande Betukumesu, Director of the National Programme for the Fight Against Trypanosomiasis in the Democratic

Republic of Congo, commented, “the majority of people suffering from trypanosomiasis believe they are suffering from malaria, because the two illnesses present the same symptoms” (ProMED 2004b). Treatment of the disease is limited to expensive toxic drugs, such as melarsoprol, pentamadine and eflornithine (ProMED 2004a).

Reduction in tsetse fly numbers plays a significant role in sleeping sickness control as well. In the past, this involved, primarily, extensive clearance of bush to destroy tsetse fly breeding and resting sites and restriction in the movement of cattle and game. Ground, or aerial, application of insecticides was not widely used because it is costly and requires considerable organization (ProMED 2004a). Recently, trapping has been used increasingly to reduce tsetse fly numbers. In Angola, for instance, the ICCT has been reported to destroy 1 million tsetse flies in the seven severely affected by the disease provinces in 2003 (ProMED 2004c). Efforts to control the disease through the above measures, however, have been hampered by lack of resources primarily (ProMED 2003a; ProMED 2004c; ProMED 2005c).

Genetic modification to the species for the purpose of mass release and introduction of these traits into the population will face the same opposition as those noted for GM mosquitoes below. A discussion of the issues regarding area-wide tsetse control is presented in Section 4.5. The conclusion from Section 4.5 is that SIT is an important component of tsetse control, capable of resulting in eradication of defined areas within an integrated programme. This section focuses on the human impact of tsetse, further adding to the case for control of this vector of disease.

4.7.3 Other issues

Many species have been accidentally introduced into new environments, sometimes with significant impacts to the native flora and fauna. Control methods for pests, such as SIT, may be directed at either introduced or native species that cause economic damage. Rarely has an entire species of insects been targeted for intentional eradication, as occurred with small pox and other human diseases. Even with tsetse control, none of the targeted species will be totally eradicated for the first decades of systematic use of SIT, since areas of greatest impact are given priority. When the possibility of a species global eradication exists, considerations of the ramifications of this decision will need to be examined.

The release of mass reared insects that are not sterile presents a different case than any of the others considered in this report. There are many ethical and environmental considerations that must be balanced before new genetic material is intentionally introduced into a species.

Section 5 The production process

5.1 The physical plant

5.1.1 Location of existing production facilities

In the past, a periodically updated list of presently operating facilities, as well as some that are pilot or research scale, appears as the *World-wide Directory of Sterile Insect Production Facilities*. A similar listing can be accessed through a country or species search on the International Database on Insect Disinfestation and Sterilization, (IDIDAS) (www-ididas.iaea.org, under DIR-SIT). Details on production capacity or current levels of production do not appear in this database.

Sterile insect production facilities for the small scale rearing of insects for experimental programmes are numerous. Larger capacity production facilities producing for commercial scale field release programmes have been limited to a few locations around the world, but have doubled in number in recent years for Medfly and NWS.

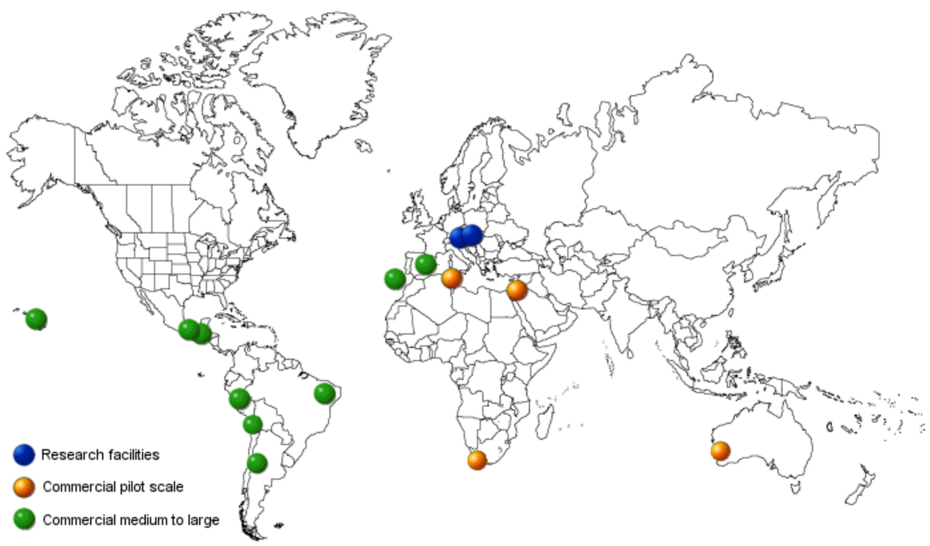

FIG. 5.1. Countries with Medfly SIT mass rearing facilities.

Figure 5.1 shows the general location for all sterile Medfly facilities in operation in 2006, above very small research rearing capacity. The three colours are to indicate the range in production capacity/purpose of the facilities. The marker at Portugal actually indicates the facility located on the island Madeira, Azores, Portugal, half way across the Atlantic Ocean. The Medfly facility shown in Hawaii is owned by the California Department of Food and Agriculture (CDFA) and produces approximately 110 million male pupae per week. These pupae are then sterilized in an USDA-owned and operated irradiation unit. The USDA/APHIS Medfly facility in Hawaii was closed in 2002 and will not be reopened, although the possibility exists of APHIS building a new backup facility in some other location (USDA/APHIS, 2006).

Figure 5.2 shows locations of facilities with significant production of sterile fruit fly species, other than Medfly, in blue. Facilities in Texas and Mexico produce *Anastrepha ludens* or Mexfly (Texas, USA and Tapachula, Mexico). Much of the production goes for the US-

Mexican border preventative release programme, which uses approximately 16 million sterile Mexfly produced in the "Moscafruit" facility located in Tapachula, Chiapas, and 12.5 million sterile Mexfly from the APHIS production facility (USDA/APHIS, 2006). The Tapachula facility also produces sterile *Anastrepha obliqua*, known as the West Indian fruit fly, and a parasite of fruit flies that can be released as a biocontrol agent concurrently with the use of SIT. The facility shown in Florida is used for production of *Anastrepha suspensa*, the Caribbean fruit fly.

The production for the sterile mango fruit fly release program in Thailand comes from a facility near Bangkok producing *Bactrocera dorsalis. Bactrocera tyroni* are mass reared and sterilized in New South Wales, Australia and Hawaii; sterile *Bactrocera philippinensis* are produced in Quezon City, the Philippines; *Bactrocera cucurbitae* or the melon fly, are in production at the Okinawa, Japan plant which sourced the successful eradication program in previous decades. The Greek facility in Crete has research scale production of *Bactrocera oleae*, along with sterile Medfly production.

FIG. 5.2. Location of existing large scale production facilities for sterile fruit fly spp, other than Medfly, and for Lepidoptera.

The FAO/IAEA Laboratory at Seibersdorf, Austria, currently maintains a large and healthy colony, expected to enable large-scale experimentation. Established in 2002 from a Greek laboratory population (IAEA 2002a), which at present amounts to about 50 000 individuals, this colony also includes a strain from the USDA-ARS Laboratory, California, colonized from wild flies collected from infested olives in that State (IAEA 2005c). This successful establishment of the olive fly colony has been attributed to improved oviposition devices and larval diet components. Nonetheless, improvements need to be made in the recovery of the larvae from the diet (IAEA 2004m). These experimental facilities are not shown on the map.

The 3 commercial-scale sterile moth facilities in operation also appear in Figure 5.2, as indicated in yellow. The Canadian facility is for sterile codling moth. Additional codling moth facilities have been constructed in Argentina for pilot trials, will be expanded there, and may be built in Brazil in the near future. Production of pink boll worm occurs at the Arizona, USA plant. Although not shown in the figure, the IDIDAS database also notes laboratory production of Asian corn borer and cotton boll worm in Beijing, China. The yellow marker in

Northern Africa is a research facility in Tunisia was developed for *Ectomyelois ceratoniae*, known as the carob or date moth (see Annex 4). Not shown is the research size production of sterile gypsy moth and cactus moth, located respectively in Massachusetts and Georgia, USA. (The Massachusetts facility now produces Asian long horn beetle for control research, as well.)

In addition to the private facility producing onion fly (see Box 3.2 in Section 3), other facilities that produce sterile plant pest species are for sweet potato weevil (*Cylas formicarius*) and West Indian sweet potato weevil (*Euscepes postfasciatus*), both located in Okinawa, Japan; and, on a research scale, red palm weevil (*Rhynchophorus ferrugineus*) in Mumbai, India (as discussed in Section 4). A research scale production of white fly (*Bemisia tabaci*) takes place in Italy.

Figure 5.3 shows the general location of production facilities for control of animal pests. The NWS facility in Panama, scheduled to open in 2008, does not yet appear on the map. The Mexico facility may close when the new facility is underway, as discussed further in the following section.

FIG. 5.3. Production facilities for sterile tsetse species and sterile screwworm. (The NWS is produced in Mexico and the OWS is produced in Malaysia.)

Several sterile tsetse facilities are operating throughout Africa. The construction of the production facility in Ethiopia was initiated in March 2002 and the first two (of in total six) tsetse rearing modules was put in operation in mid 2006, representing the start for large scale sterile male production. The facility in Burkina Faso may also expand production, and the construction of a tsetse factory is also being planned, making use of the AfDB loan. At the moment it is unclear whether large-scale production facilities, particularly in Uganda and South Africa, will be developed, although the production plans for several plants remain dynamic. In Europe, facilities include small production for research and varietal maintenance in Siebersdorf, Austria and for rearing in Bratislava, Slovakia. The latter acts as insurance (see discussion in Section 3.5.5) against loss of colonies at the larger production facilities.

5.1.2 Resources for design of facilities

The basis for the design of these facilities around the world has been a combination of expertise in industrial buildings in general and the specific experience of facility managers for sterile insect production. Historically, much of the latter was transmitted through in-person, on-site informal training or internal memos tracing changes and adjustments to the designs (e.g. to the cooling systems), rather than through any published record.

The longest running sterile insect operation to date is the sterile NWS facility in Tuxtla Gutierrez, Mexico. Until now the only NWS production facility in the world, this facility has been operating since 1976. Due in part to better funding of the programme, this facility is in good condition and could last another 25 years with regular maintenance (Sheesley *et al*., 2001). "Lessons learned" from this facility are being integrated into the new facility under construction in Panama. This transfer of information was facilitated by the fact that the planning and operation of the new facility involves the same governments and to some extent even the same individual staff members. With the construction of a new facility nearing completion in Panama, all operations will move unless a decision is made to maintain the facility in Mexico as a backup supply.

FIG. 5.4. The largest Medfly production facility: El Pino in Guatemala.
(Photo courtesy of the Mosca Med Program, USDA/APHIS)

There is also only one Old World Screwworm (OWS) facility operating, which is located in Malaysia (see more discussion in Section 4.6). If an OWS control programme using SIT goes forward in the Middle East, an additional facility will need to be constructed. Again in this case, expertise regarding the design of screwworm facilities will probably be shared through bilateral cooperation or through international facilitation by IAEA, rather than by means of extensive literature, guides or software on the subject.

While the NWS facility is the longest running, the broadest experience with sterile insect facilities is in the design, construction or conversion of an existing building to sterile fruit fly production facilities. Of these, the largest is the Medfly facility is El Pino, shown in Figure 5.4. In the earlier plants, resource limitation sometimes caused managers to rely on “makeshift” solutions when original equipment or design was found lacking. For example, the need to control air flow and humidity led to the addition of simple window units for air conditioning and manually operated humidifiers using untreated water in the Petapa Medfly plant in Guatemala before more biosecure improvements could be funded. Subsequent facilities, such as Moscafrut in Metapa (see Section 4.2) which opened in 1993, there is more attention to the climate control requirements. The materials preferred have changed over time as well after observing corrosion due to the fruit fly metabolism secretions, reagents used, chemical changes in the diet and overall tropical conditions of some locations (Caceres, 2001; York Austria, 1998).

The more recent sterile fruit fly production facility designs can be much improved based on discoveries over the past two decades of experience with these earlier, large scale facilities. Thus the FAO/IAEA Joint Division of Nuclear Techniques in Food and Agriculture has provided expert advice on the design of new facilities for many countries, most recently for sterile Medfly production in Israel, Spain and Brazil. As experiences are collected regarding the minimum size of the facility, the best design for equipment, appropriate capacity for waste treatment and so forth, FAO/IAEA is able to transfer this information directly as well as through hosting exchanges among facility operators.

Biological parameters, measurements of quality control and rearing parameters for Medfly have been translated into equipment, diet volume and rearing area for the initial design of facilities to calculate automatically the minimum size of the rearing area. These observations are useful for predicting the area needed for production of other fruit fly species as well, although differences will arise between genetic sexing strains and the existing strains that still require both male and female mass rearing. From these various inputs, it is easy to calculate the capital outlay for the complex using the local prices for equipment and construction costs (i.e. per m^2).

The biological requirements for mass rearing Lepidoptera indicate greater equipment precision than has been employed for fruit fly and screwworm production in the past (although these species benefit from greater precision as well). For example, for codling moth the air humidity must be adjusted downward over the course of the rearing period (from 75 to 55 percent relative humidity), until finally in the emergence phase the climate should be controlled so that the diet is dry enough (20 percent relative humidity) for pupae to emerge (York Austria, 1998).

The first attempts to mass rear codling moth at the Osoyoos, Canada, facility – pictured in Figure 5.5 – met with equipment failures, often related to the strict sanitation required for production of Lepidoptera. For example, microswitches on the diet feeding lines were not water or dust proof. However, significant increases in production – from an initial goal of 5.3 million sterile adult codling moth per week to the actual weekly output of 15 million – are attributed largely to improvements in the process control (Bloem and Bloem, 2000). Additional sterile codling moth production facility will open in Argentina in 2008 and another is planned for Brazil in the near future.

Air quality is also of vital importance to the staff working in Lepidoptera facilities; dust or scales from the wings of moths are a major health hazard due to the allergic response they invoke in many people. The Osoyoos, Canada, codling moth facility employs high efficiency particulate arresting (HEPA) filters for rearing rooms, in conjunction with the state of the art air distribution system (York Austria, 1998). This level of filtration is recommended for all types of facilities to help restrict entry of pathogens and other airborne contamination from fresh air supplies. In general, the heating, ventilation and air conditioning (HVAC) system is one of the most important aspects of a facility design for moth production.

FIG. 5.5. The codling moth rearing facility in Osoyoos, British Columbia, Canada.
(Provided by the photo gallery at http://www.oksir.org/gallery.htm)

The most recent set of sterile insect production facilities coming on line are for production of various species of tsetse. A list of all of the tsetse production facilities operating or under construction is presented in the IDIDAS database. A description of the facilities in East Africa, the potential demand for that region, radiation dose, staffing and other parameters appears in Section 4. The same information will be developed for South and Central Africa over time.

Again, little is published on the construction design so far, as most planning depends on the sharing of experiences among facilities. The use of semi-automated production units for tsetse was first described by Opiyo *et al.* (2000). This concept has been refined and developed over the past ten years at both the IAEA/FAO Laboratory in Sieborsdorf and in some of the African facilities. Such innovations have led to vastly improved production systems, but much work remains to be done.

Commercial scale mosquito production is not yet in place. There has been extensive preparation for mass rearing key species. For example, aluminium heating plates were introduced in larval trays in order to obtain optimal water temperature and to induce daily temperature fluctuation patterns. Evaluations of the impact of various temperatures on larval growth and adult energy reserve accumulation have also been conducted (IAEA 2006e). Such discoveries will be employed in larger scale production when that phase is reached.

5.1.3 Adaptation of an existing building or purpose built

Although most facilities have used a purpose built structure (e.g. the Madeira facility in Figure 5.6), it is not necessary and there may be advantages to adapting existing buildings, particularly for smaller projects. Section 3.3.3 explains the influence of having buildings with alternative uses on the valuation of the property.

FIG. 5.6. Purpose built Medly production facility in Madeira, Portugal.
(Source: Madeira-Med Web site, 2001)

In the early 1980s in Western Australia, a pre-existing building was adapted to rear and sterilize 12 million sterile Medfly per week (both male and female) to combat an outbreak of Medfly around Carnarvon (north of Perth). Eradication in that area was achieved by 1985, but without adequate quarantine measures, the transport of infested fruit from the southwest soon resulted in re-infestation. In the meantime, a detection of the Queensland fruit fly (or "Qfly", native to Eastern Australia) in Perth led the government to build a new production building, salvaging the old irradiation source from the original Medfly programme. That facility had a capacity to produce 30 million Qfly per week, which were used with other methods to achieve the statewide eradication of Qfly in 1991. Subsequently in early 2000, the same facility was again employed for producing Medfly, this time 5 million sterile males per week for use in a pilot control project at Broome, in the northern coast of Western Australia (Sproul, 2001).

The same production facility may be expanded again if plans for eradication or suppression of the Medfly in Western Australia go forward. Costs of production would need to be lowered to compete with imported Medfly (Mumford *et al.*, 2001), but there may be an advantage to having a local facility both to begin and end the multiple-year project or as a backup production. In the meantime, South Australia has purchased 2 million sterile Medfly males per week over several months to release in conjunction with detected outbreaks around the city of Adelaide (Sproul, 2001 and see Section 4.2).

The major difference between this size facility and other, larger ones is the need for waste treatment at the site. Western Australia's facility uses pre-existing waste stream removal and municipal water treatment, whereas most purpose built facilities include a small wastewater treatment operation at the same location.

The possibility of conversion of a facility is not limited to small scale, however. The Tuxtla NWS facility already has 20 percent of its area in use for diagnostics laboratories, in anticipation of the NWS production moving to Panama (Sheesley *et al.*, 2001). Another use of this facility is to supply eradication programmes in the Caribbean. The Tuxtla facility currently provides 30 million sterile flies to Jamaica for this purpose. Cuba, Haiti and the Dominican Republic are other potential customers for the Mexican production once the Panama facility is in operation. These types of potential future use can influence decisions regarding the construction of the original facility, as can the availability of appropriate existing structures.

5.1.4 Single facility or modular approach

There is increasing interest in designing facilities in modules in order to increase production in step fashion – either by sequential construction of the modules or by expansion into other modules over time or in conjunction with seasonal demand. Independent modules provide a backup facility in the case of a pathogen or environmental toxin. In single units contamination could decimate the breeding colony directly or cause losses by contaminating the larvae and rearing areas. Of course, modules at the same site are not useful as backup when the problem arises from something such as water or diet quality, labour unrest or other issues that will impact everything at the same site. The value of the modules as backup insurance is enhanced when separate electricity generators and water pipes are used, however, as is done in Moscafrut in Metapa (W. Enkerlin, pers. comm., 2002).

Another advantage of modules is in the case of introduction of a new strain for a new colony. For example, the NWS strain that was effective throughout Mexico and Central America may be less accepted by the Jamaican endemic population. Because the primary purpose of the Tuxtla plant, and the proposed one for Panama, is to provide sterile NWS for a barrier in Southern Panama and for potential SIT eradication programmes in the Caribbean, the most reliable way to also provide production from a different strain is if the facility were divided into modules. The proposals for a Panama facility for NWS have featured two or three modules, but the final plans are not yet approved for US Government funding (Sheesley *et al.*, 2001).

Modules may also be built with the anticipation of mass rearing multiple species at the same location. At this time, there is only one large scale fruit fly facility that is producing more than one species simultaneously: the Moscafrut facility, which produces two species of sterile *Anastrepha*, the West Indian fruit fly (*A. obliqua*) and the Mexican fruit fly (*A. ludens*). As many as three species of tsetse have been produced at a time (in the tsetse rearing facility at Burkina Faso) in a single facility with most production plants, such as the one in Uganda, limiting production to one species. Presently the only modular sterile tsetse production facility is the new facility in Ethiopia (seen in Figure 5.7), with the plan to expand using modules as the demand warrants.

Modules can also be spread across geographic areas, in the sense that production/irradiation and release may be separated by great distances. For some time, irradiated Medfly pupae have been shipped across international borders for holding, emergence and release. For example, the South African facility formerly imported Medfly pupae (10 million/wk) from El Pino, Guatemala, until more consistent production was achieved at their own site. For a few years, Israel was shipping pupae (10-15 million/wk) from El Pino which were held and emerged in a "release centre" until last year when a small rearing facility was opened there. Spain has been shipping Medfly pupae from the Argentina production facility (20 to 30 million/wk) until 2007. Madeira Med facility has also supplied irradiated pupae to various foreign programmes. Tunisian private industry invested in a holding and emergence centre near Cape Bon for receiving Medfly pupae from the rearing and sterilization facility of the Centre National des Sciences et Technologies Nucléaires (CNSTN) located few hundred kilometres away in Tunis (see Annex 4).

FIG. 5.7. Top-view of the tsetse factory at Addis Ababa Kaliti, Ethiopia.
(Courtesy of U. Feldmann, 2004)

Examples of large scale and ongoing shipments are the sterile pupae being shipped from El Pino to Los Alamitos release centre in California (at least 300 million/wk) and Sarasota in Florida (at least 150 million/wk). A full record up to 2003 of shipments of sterile insects from the production facilities to foreign countries for release appears in Enkerlin and Quinlan (2004). Taking this approach a step further, the Metapa facility in Mexico has eliminated its bisexual breeding colony and it is routinely importing Medfly eggs of the male only strain from El Pino facility in Guatemala for production of 500 million sterile male flies per week. This technology has been developed at the Entomology Unit of the IAEA in Seibersdorf from where a number of small volume shipments of Medfly eggs for colony replacement or colony start-up have been carried out successfully (e.g. Brazil, Peru, Tunisia, Spain)(Cáceres *et al*. 2007a, Maman and Cáceres 2007).

An innovative modular approach, and possibly a niche market, for a private business to consider is to have a production facility producing eggs that are then shipped to be reared and sterilized at some distribution location (see Section 5.4). Research on decentralised egg shipping technology forms part of the EU-funded Cleanfruit project, which will have results published in 2007. This project also is investigating the canister design for shipping eggs, the protocols for cross-border shipping (including recognition by plant protection authorities), and the possible design for a male-only production facility. In principle, this approach could be feasible for a number of mass reared insect species including fruit flies, codling moth, and screwworm. Other emerging technologies that could affect production by modules are discussed in section 5.4.3.

FIG. 5.8. The tsetse rearing facility at Tanga, Tanzania.
(Courtesy of A. Parker, 2004)

5.1.5 Automated or manual labour

Most facilities have been located in countries where labour rates are sufficiently low to permit employment of numerous technicians, for example, in the case of Medfly production in Chile, Argentina and Peru.

Facilities have also been constructed in locations with high labour rates. The Japanese production facility for sterile melon fly *(Bactrocera curcurbitae)* was by far the most automated one to date. The facility (shown in Annex 7) featured state of the art automation for preparing rearing trays and moving them through the rearing process. This approach is best seen in the video prepared by the Japanese Government: *The Sterile Insect Technique for Control of Melon fly*.

The usefulness of automation for aspects of the production process is not limited to locations with high labour costs, however. Parker (2005) describes various conditions under which automation improves the overall production process, including reduction in human error and increased consistency, reduction in microbial contamination and increased efficiency in utilization of space.

For example, handling of moths can cause damage, therefore research in Tunisia, drawing on the Canadian SIT experience with codling moth, resulted in improving some components of the date moth mass rearing (IAEA 2003b). First, mating and oviposition are taking place in the same cages, which are cylindrical and lined with removable paper sheets that are very suitable for egg deposition. The cages are kept in an acclimatised room and are slowly rotated to ensure equal light distribution. High female fertility and random distribution of eggs on the paper sheets suggest the efficiency of this system. Trays (instead of closed containers), containing a suitable larval diet and the oviposition sheets with about 2500 eggs each, are placed in trolleys. Each trolley contains about 85 trays. The Tunisian experimental production unit also developed a moth collection system, consisting of (a) a light trap (placed in the dark, acclimatised room where the trolleys with the pupae are kept), (b) the collecting devise (placed in an adjoining cold room) and, finally, (c) the duct that connects the two components. Emerging moths are attracted to the light trap, sucked into the duct and then carried to the collecting devise where they are immobilised. The system reduces the labour cost involved in the manual collection system used for research purposes. It also ensures the selection of high quality moths for release through the elimination of weak moths or poor flyers. (See also Annex 5.)

Questions of modularity and automation also arise in experimental operations. Since mid-2003, the project has established three colonies of mosquito species able to vector human diseases (see also Section 4), in this case *An. Arabiensis*, to be used in various studies, using populations from Zimbabwe, Central Sudan, and Northern Sudan. Improvements in mass rearing methods, such as membrane blood-feeding of adult females, brought about a rapid expansion of the colonies with daily production reaching 5-7 thousand pupae (IAEA 2004i; IAEA 2004n).

A modular cage for mosquito rearing and production was constructed that can accommodate the production of 100 000 sterile males per day. Features of this cage include an artificial 'horizon', resting areas and tubes for sugar and blood feeding and collection of eggs. Currently, improved feeding devices are being developed to further minimise intervention inside the cages and to maximise their holding capacity (IAEA 2005f; IAEA 2006e). Other research activities focused on establishing appropriate non-invasive methods for sex separation. Near-infrared spectrophotometry and sex-specific wing beat frequencies were considered as potential targets for sexing large numbers of pupae and adults in mass rearing settings (IAEA 2004i). Preliminary experiments demonstrated the feasibility of using automatic egg and larvae counting systems. Further improvements are needed to ensure the efficiency of these systems (IAEA 2006e).

A study on the correlation between larval crowding and the mating competitiveness of *An. gambiae* concluded that low crowding enhanced the competitiveness of sterile males but reduced their longevity. It also revealed that, although crowding conditions did not affect the mosquitoes' body size and teneral reserves significantly, larger males mated more successfully than smaller individuals. Finally, the study recommended addressing the issue 'reduced fitness of transgenic mosquitoes' via the manipulation of the environmental conditions of the larvae (IAEA 2006g).

5.2 Operations of a sterile insect facility

There are several steps leading to the release of sterile insects in an SIT programme. Figure 5.9 shows the steps for sterile fruit fly production and release.

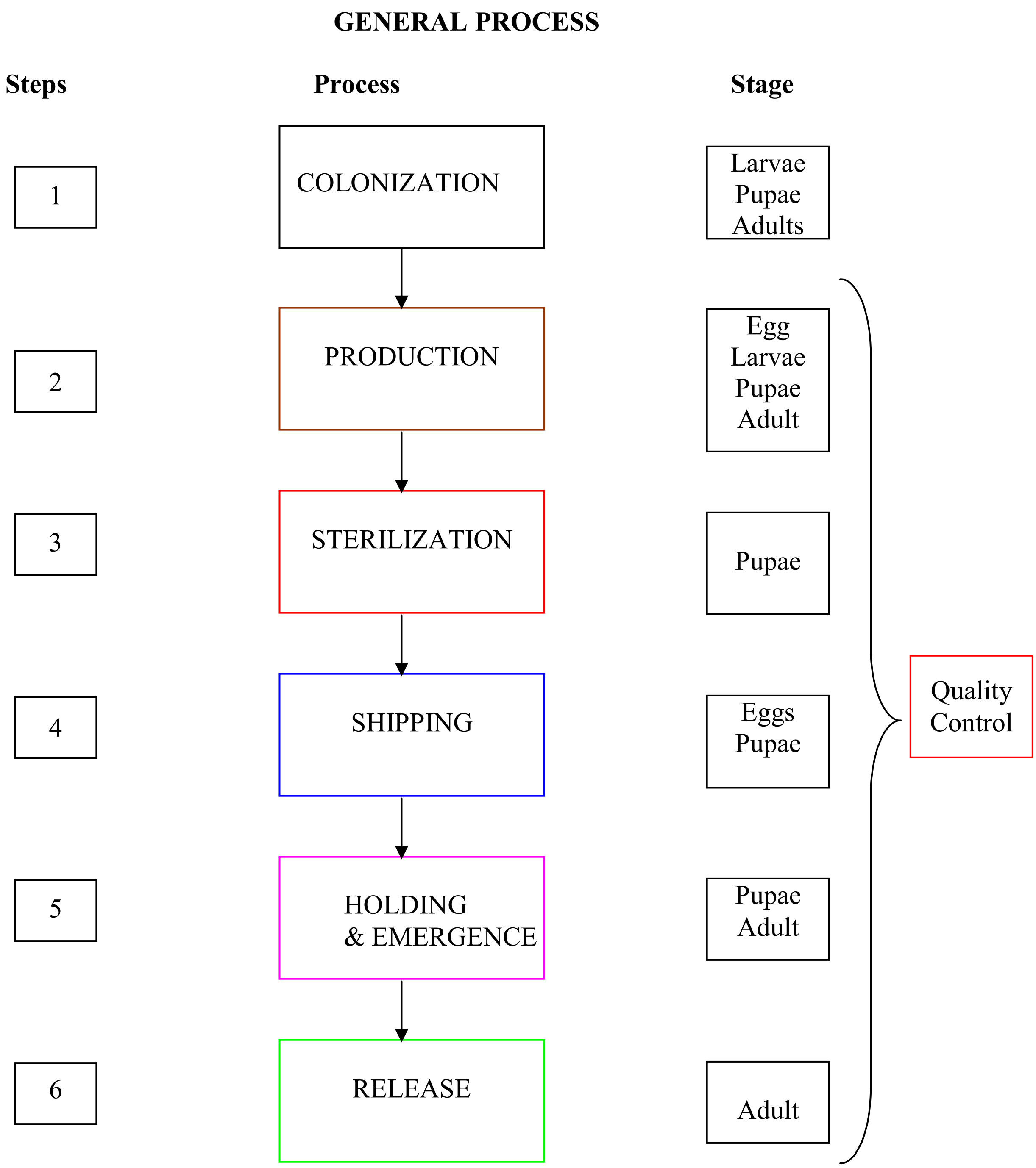

FIG. 5.9. Schematic of the overall process of production of sterile fruit fly species through to their release for an SIT programme (Source: Enkerlin 2001a).

The production component generally consists of mass rearing, sterilization, packaging and shipping all from a single location. (See previous section for the alternative approach that divides egg production from the subsequent steps.) The holding and adult emergence often take place at a different location, even if the production is nearby the final release site. Quality control, in various forms, must follow the entire process through to the field. Recent advances in quality assurance for sterile fruit fly production are outlined in Cáceres *et al*. (2007b). More detailed schematics of each part of the production process appear in Annex 7.

5.2.1 Issues related to diet

Future trends in operations include experimentation with diet substitutes. Artificial diets must provide the species with all that it requires to complete its life cycle without affecting viability and behaviour. The use of antibiotics and antispoilage compounds in these diets can be problematic as many insects depend on symbiotic gut microbes and their destruction can cause developmental and behavioural problems. Manipulation of the diet may provide changes in the environment of the facility, if problems arise for the workers due to mould spores, mites or other allergens (Parker 2005). Changes in the diet are generally made in order to reduce the costs, take advantage of a local supply of some material, reduce risks (e.g. from blood), reduce problems with waste that results from used diets or to cut down on the heat generated from the diet's chemical changes. For Medfly production, for example, the diet ingredients constitute over 30 percent of the total product cost (see Section 7). Any change must maintain or improve the productivity and quality of the breeding colony and the insects produced for release.

Some major changes to diet for rearing *Bactrocera* species, described in Chang et al (2004), consist diets based in hydroponics. This type of diets would substantially reduce rearing space and would be much less labour intensive. The waste from spent diet – an important environmental issue and cost to facilities – is also virtually eliminated.

5.2.2 Increasing interest in environmental certification

The International Organization for Standardization (ISO) was established over fifty years ago to develop voluntary standards in a wide range of industries. One Technical Committee of ISO develops standards on environmental management (ISO 14000 series), which have been applied to numerous commercial operations as a mark of compliance with internationally recognized environmental standards. In addition to complying with existing regulations and customer requirements, the ISO management series (9000 and 14000) both require organizations that are certified to continually improvement performance against their specific objectives in quality and mitigation of impacts.

The production facility in Mendoza, Argentina, has obtained ISO status for the environmental management of its operations. Bio-Fly Ltd. also achieved ISO certification, but in the 9000 series relating to quality management. The application of these generic management system standards to sterile insect production operations has been considered and endorsed in meetings of experts (e.g. the Fruit Fly Working Group of the Western Hemisphere) and are likely to be sought by managers of other sterile insect facilities in the future.

5.3 Addressing possible hazards

The most technologically developed countries in the world today are not always able to regulate, manage and monitor the uptake of new technology as quickly as it emerges from the research sector. Even when a technology is developed to "benefit humanity", most developing countries will be challenged by managing the risks presented by the technology (UNDP 2001). These countries may lack the policies and institutional structure required for management of the risks and may, therefore, lose out on the benefits of the technology or proceed to use it without due consideration. For this reason, this section attempts to cover some generic hazards for sterile insect production, although each case must be considered separately in view of reducing risks.

Possible events that may lead to hazards from the production phase, during shipping or due to release are identified in Box 5.1 and discussed further in this Section. Once hazards to the environment and to people are addressed, the primary concern for sterile insect production will be to manage hazards to the breeding colony itself, which fall under quality assurance procedures.

Box 5.1 Events that may lead to hazards to the environment or people from sterile insect production, shipment and release may be managed

DURING PRODUCTION

- Breeding stock or diet arriving to the facility brings contamination (parasite, bacterial, etc.) that survives the sterilization process
- Diet arriving to the facility has:
  - biological contamination of threat to humans (e.g. blood borne disease, fungus);
  - allergen or other reaction from frequent exposure.
- Facility operation – (same as other manufacturing plants except as noted in Sections 5.1.1, 5.3.2, etc)
- Disposal of wastes if contaminated as above
- Escape of mass reared insects from production facility prior to sterilization

DURING SHIPPING AND RELEASE PHASE (if conditions are not controlled during production)

- Shipment of sterile insects with some biological contaminant (e.g. parasites)
- Shipment of insects not properly sterilized:
  - And handling along route allows escape (and/or)
  - And released at destination without realising they are fertile
- Insects not properly sterilized transfer genes to wild population through reproduction

The level of this risk then depends on the potential consequences from this new population's genetic input to the wild population.

The identification of a possible hazard does not constitute any consideration of the risk it poses, or likelihood of its occurring. ***None of the above events are likely to occur under the usual SOPs.***

Based on discussions of the FAO/IAEA 2001a and Quinlan and Enkerlin 2003. See Section 5.4.1.

5.3.1 Best practices and SOPs in production

For some time, the FAO and IAEA Joint Programme has produced standard operating procedure (SOP) documents useful for the production, sterilization, quality control and release of sterile insects. Principal among these are:

FAO/IAEA. 2001c. Gafchromic® Dosimetry System for SIT, standard operating procedure. Joint FAO/IAEA, Division of Nuclear Techniques in Food and Agriculture.

IAEA. 1992. Laboratory Training Manual on the Use of Nuclear Techniques in Insect Research and Control - Third Edition. IAEA Technical Reports Series No. 336.

Best practices and standard operating procedures (SOPs) for sterile fruit fly production facilities have been elaborated largely through collaboration among the several countries with the longest history of production. This was done for Medfly primarily based on the experiences of the USA, Mexico, Guatemala and Argentina. Production facility managers in any location are able to address possible hazards by developing their own SOPs, based on the international guidance available. The development of these best practices is ongoing and dynamic. There is also an unusual level of cooperation in training and on-site consultations that has been facilitated by IAEA, but also occurs on a bilateral basis. This further assures the technical "know how" for addressing possible hazards.

After safety, the efficacy of the SIT in any given situation is the primary concern of any programme. The failure of eradication attempts against a Medfly incursion using SIT in northern California in 1981 demonstrated the need for having a supply of known quality sterile flies (Calkins *et al.* 1996). Quality control standards and analysis of data are now a more integral part of all sterile insect production operations.

FAO, IAEA and United States Department of Agriculture (USDA). 2003. Product quality control and shipping procedures for sterile mass-reared tephritid fruit flies. Version 5.0.

FAO/IAEA. 2003. Trapping Guidelines for Area-Wide Fruit Fly Programmes.

FAO/IAEA. 2007. Guideline for Packing, Shipping, Holding and Release of Sterile Flies in Area-Wide Fruit Fly Control Programmes.

These documents consist of recommendations reached by consensus by an international group of fruit fly experts. They will be revised regularly to reflect new developments in the field.

In 2001 a Consultant's Group drafted guidance on transboundary shipment of sterile insects, to harmonise regulations of (in particular transit country) in support of the increasing commercial movement of sterile insects. Although it was prepared with an emphasis on plant pests, most of the recommendations cover transboundary shipment risks from animal pests as well (Quinlan and Enkerlin 2003). Since that time, SIT has been included in the revision of an earlier International Standard for Phytosanitary Measures (ISPM), as detailed in section 5.10. These conclusions on shipment, however, are available on the IAEA website as another supporting reference for the development of national policy and regulation.

IAEA has coordinated the development of these international procedural manuals, but in fact they are based on years of experience in individual production facilities. Each production facility must prepare its own SOPs covering production and sterilization, as well as addressing shipping of the product and other points at which hazards may arise. Individual facilities may interact with FAO/IAEA to develop new or revise existing international manuals and guidance documents. An outline of the topics normally found in a site-based SOP appears in Annex 8.

5.3.2 Special hazards for mass rearing animal pests

As yet, there are no international consensus guidelines for mass rearing screwworm or tsetse fly species. There has been little need for screwworm because of the concentration of production in one facility for NWS and one for OWS. For tsetse, presently each factory has its own procedure manuals, which in the future may be used to create a harmonized international SOP. A draft *FAO/IAEA Guidelines for Conducting Baseline Surveys for Tsetse Area-Wide Integrated Pest Management Programmes* should be finalized by 2007 after review by various partners in 2006.

Animal blood is used as the food source when rearing animal pest species such as tsetse fly or screwworm. Quality control of the blood is extremely critical for the well being of the colony, as the introduction of many veterinary drugs or pesticides can damage the feeding insects. Despite passing through routine bioassays, blood quality appeared to be the reason for reduction of tsetse colonies in 2006 in Austria and Slovakia (IAEA 2007b). From the human perspective, there are a number of diseases that can occur in animal blood that also infect humans. Examples include anthrax, Rift Valley fever, Q fever, tularemia, anaplasma marginale and tuberculosis. Two categories of hazards may exist from using this animal product for sterile insect production: the hazard to workers in the facility, and the hazard of introducing an animal disease to an area previously uninfected. The third possible hazard, an impact on consumers, is irrelevant to this type of industry since there are no human consumers for this product.

Both of the potential hazards are considered highly unlikely. First, workers in a sterile insect production facility generally will not be handling the blood directly, so there would be no exposure. Most of these disease agents of concern are monitored or treatable if a human should become infected. Second, if a local source of blood is used, there is no hazard for introducing exotic diseases. When the source for blood is not immediately local, it is generally dried or frozen for transport to the facility and remains within containers until use. Furthermore, the routine irradiation of blood supplies eliminates many pathogens, if any were present.

Irradiation may not be sufficient to deactivate prions, however. Prion diseases such as bovine spongiform encephalopathy (BSE) and scrapie have been shown to be transmissible to other animals by blood, although this is not the most common mechanism for transmission (Houston *et al.* 2000; Hunter *et al*. 2002). The BSE has been strongly linked to human new variant Creutzfeldt-Jakob disease (nvCJD) (e.g. Hill *et al*. 1997).

One way to lower the already highly unlikely risk of utilizing ruminant blood contaminated with BSE is to source it from locations with no or low risk ranking[15]. Another way is to

[15] Risk of prion diseases in animals has been estimated based on genetic vulnerability, food intake and geographic location. The European Commission set up various scientific committees in 1997 to address the concerns. These and other groups developed a list with rankings for risk, based on its assessment of the amount of live cattle and meat-and-bone meal imported into countries in question (last updated 2003) and a model for prediction of risk, which has been validated over time. In 2003, these responsibilities were passed to the European Food Safety Agency. A review of the geographic risk and comments on the risk model are found on the European Commission website: (http://europa.eu.int/comm/food/fs/sc/ssc/outcome_en.html).

source blood only from animals routinely tested. The Food Standards Agency of the EU continues to conduct checks, using Western Blot analysis (Prionics Check) and Platelia-BSE Bio-Rad tests, on all imported beef and test every bovine animal over the age of 30 months within Europe. Through this monitoring in 2005, BSE cases were found in all EU Member States except Cyprus, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Finland and Sweden. The number of BSE cases and the overall prevalence in tested animals decreased by respectively 35 % and 29 % in 2005 compared to 2004 indicating that measures taken are having some effect. However, given the long incubation period of BSE, it will take many years still before eradication of BSE in Europe (European Commission, 2006). Therefore, special precautions must be taken at the time of collecting the blood either by sourcing from country that has negligible risk or from a supply that checks each slaughtered animal for BSE and certifies the blood. In case of the latter, this will add some expense that is not presented in the Slovakia study, and may even require import of blood if a local supplier with the testing capacities is not identified.

None of the experts contacted during the original study for the Model Business Plan believed that an insect could transmit such a disease agent after ingestion. However, due to the current level of uncertainty and the potential consequences of spread of BSE, it is recommended that a sterile insect production facility manager periodically update his or her information on incidence of the disease and mechanisms for transmission to determine any necessary control of this hazard. Presently, there are no reported cases of BSE in Africa, where the tsetse control programmes are taking place. On the other hand, it is unlikely that these herds are being routinely tested.

Although additional research may show that the risks from the blood diet are negligible, efforts are under way to find substitutes for blood. This research is driven more by cost considerations and the need for high quality, consistent supplies than by any fear of disease. Yet any discoveries for cost saving objectives will also lower the risk from the potential hazard of disease transmission to other animals or humans.

5.3.3 Biosecurity at production site

Production facilities should prevent escape of the organisms they are mass rearing. In some cases, this has not been a matter for serious consideration because the insect species in question either already exists in the surrounding countryside or could not survive and spread in the natural environment of the facility's location. A good example of a production facility located in an area in which the mass reared insect (a) could survive if it escaped (b) is a quarantine pest and (c) has been eradicated is the Tuxtla Gutierrez, Mexico, facility that produces sterile NWS.

The NWS facility operated for over 25 years without any recorded accidental release until a single incident occurred (Parker, 2005). The biosecurity programme includes the use of sentinel animals on the grounds of the facility and traps. Approximately 3 million sterile NWS are released around the production plant as an additional shield against the establishment of any escape of a fertile female insect. A recent external review judged the likelihood of an escape to be very low (Sheesley *et al.,* 2001). The factors contributing to the survival of an escaped insect are the same as those facilitating an outbreak from an introduction. These are outlined in Box 5.2.

Box 5.2 Potential risk of outbreak
Screwworm Review Team Discussion

The potential risk for an outbreak (i.e., establishment of a breeding population) of screwworm is a complex matter that is not well understood. Biotic factors that influence the risk include such things as number and life stage of introduced specimens, type of habitat, number and kind of hosts, migration of hosts, migration of flies, etc. Abiotic or physical factors include temperature, rainfall, humidity, time of year, vigilance, and mechanized transportation of infested animals, etc.

A few of the factors influencing the possibility of an outbreak are listed below:

Biotic Factors Favourable for an Outbreak:
1. Introduction of a large number of specimens
2. Introduction of gravid female flies
3. Forested habitat
4. Large number of susceptible hosts
5. Migration of infested hosts into forested habitats

Biotic Factors Unfavourable for an Outbreak:
1. Introduction of one or a few number of specimens
2. Introduction of larvae
3. Non-forested habitat
4. Few or no susceptible hosts
5. Migration of infested hosts into non-forested habitats

Abiotic Factors Favourable for an Outbreak:
1. Moderate temperature (around 80°F=26.6°C)
2. Moderate rainfall
3. Moderate humidity
4. Spring or early summer introduction
5. Poor vigilance
6. Transporting infested animals

Abiotic Factors Unfavourable for an Outbreak:
1. High or low temperatures
2. High or low/no rainfall
3. Low humidity
4. Late fall or winter introduction
5. Good vigilance
6. Transporting uninfected animals

Source: Sheesley *et al.*, 2001.

A surveillance and monitoring programme has been carried out under the NWS programme for many years. This programme is being considered as a model for surveillance for other animal (primarily cattle) diseases in Mexico and Central America (Panama already has such a programme) (Sheesley *et al.,* 2001). Quarantine operations have been improved in each country as a result of the area-wide control programmes using SIT. Sharing of laboratory facilities and expertise is also encouraged across animal disease commissions. Such synergy will enhance the trade benefits of eradication of one disease through SIT, even to support the control or eradication of other pest species that may not be appropriate for SIT approach.

Unique incidents of escape or accidental release of non-sterile fruit flies occurred in Japan with the melon fly (Parker, 2005) and, anecdotally, with Medfly in California. Although the latter may have been the result of poor retention of the fluorescent dye marker used for sterilized Medfly, it did lead to a regulatory response.

5.3.4 Emergency preparedness plans and security

As with any industry, a sterile insect production facility requires an emergency preparedness plan and considerations of security of the plant. An outline of the requirements appears in Annex 8.

The NWS programme's assessment of vulnerability to natural disasters showed that an earthquake could allow a massive escape of fertile NWS that would require control (Figure 5.10). Tuxtla, in fact, lies on a major earthquake fault line. This situation would be managed in a similar fashion to outbreaks that have occurred from the introduction of infested animals to zones that are otherwise free from the pest. Although it could take some time for this area in Mexico to be declared free of NWS after such an event, the likelihood of serious damage from an earthquake occurring is extremely low.

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NEIC: Earthquake Search Results
            U. S. G E O L O G I C A L  S U R V E Y
             E A R T H Q U A K E  D A T A  B A S E

FILE CREATED:  Wed Mar 14 07:02:02 2001
Geographic Grid Search   Earthquakes=        4
Latitude:   18.000N  -   16.000N
Longitude:    92.000W  -    94.000W
Catalog Used: NOAA
Data Selection: Significant Earthquakes World Wide (NOAA)

CAT   YEAR   MO DA ORIG TIME   LAT    LONG  DEP  MAGNITUDE   IEFM DTSVNWG DIST
                                      NFPO        km
                                      TFS

NOAA  1902   09 23 2018       16.60  -92.60 100 8.39 MsNOAA  .D.. .......
NOAA  1914   03 30 0041       16.80  -92.20 150 7.50 MsNOAA  .... .......
NOAA  1935   12 14           16.50  -93.10                .D.. .......
NOAA  1954   02 05 1517       17.30  -92.60 100 6.20 MsNOAA  .C.. .......

Search Result:  4 earthquakes at Tuxtla, biggest was M8.39 in 1902.
Last major earthquake in 1954:   M6.2
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FIG. 5.10. NWS site earthquake survey results (Source: Sheesley *et al.*, 2001).

For sterile insect production facilities, there is also international guidance for safety of any irradiation source. Such a highly regulated industry may prove to be safer than other industries that have no international guidelines or SOPs. Useful references for irradiation source safety appear in Annex 8.

5.4 Logistics and transport issues

5.4.1 Current practices in transport and handling

Transboundary shipments of sterile insects have been occurring for nearly 50 years, yet there have been limited guidelines to guide this activity. The "*Manual of Nuclear Techniques in Insect Sterilization*" (available on IDIDAS) provides information on shipping procedures for mass reared tephritid fruit flies for sterile release programmes, as do the SOPs by FAO, IAEA and USDA (2003) and the recent *Guideline for Packing, Shipping, Holding and Release of Sterile Flies in Area-Wide Fruit Fly Control Programmes* (FAO/IAEA 2007). These new guidelines incorporate some of the recommendations from an FAO/IAEA Consultants Group, focusing on SIT for pests of plants that met to identify and evaluate possible hazards of transporting sterile insects, even though these hazards have not come to pass historically. Over the next few years, transport and handling will be included in the SOPs for tsetse and eventually for other species not already covered.

The four main hazards identified included the introduction of exotic contaminant organisms, which is a hazard in the transportation of any commodity. Other hazards identified would require that a series of events all coincide to allow for the release of a fertile quarantine pest in transit or at the destination. These hazards could have significant consequences, but were valued as extremely low risks due to the unlikely chance of the combined negative events occurring (FAO/IAEA 2001a).

The Consultants Group recommended formalizing the steps to be taken both during production and after leaving the facility to ensure that sterile insect transportation remains safe. Finally, harmonized guidance regarding insect pests of livestock and insects of medical importance controlled by SIT was recommended for development by the appropriate bodies. These issues were discussed further by Enkerlin and Quinlan (2004).

5.4.2 Recent developments

The possibility of shipping insect eggs as opposed to pupae (or adults for some species) to rearing and release centres could increase the efficiency of large SIT programmes. Once developed, large facilities will produce eggs, for example from Medfly genetic sexing strains, that will be transported to satellite facilities where only males have to be reared, sterilized and released. Experimental tests on egg storage for test shipments were successfully conducted between the El Pino facility in Guatemala and Seibersdorf Laboratory in Austria (IAEA 2002f) and between Seibersdorf and South Africa. By shipping eggs there would be essentially no threat of establishment of this species in transit, since any mishap would result in their death. For some species, the commercial value added would come later in the chain, possibly with the purchaser so that it would be less lucrative to attract private investment, unless the same company is involved at the distribution end. In addition, shipping Medfly eggs would eliminate the high cost and the risk of maintaining in the production facility the genetic sexing breeding colonies.

5.4.3 Future trends

Reduced temperature (e.g. 20°C instead of 25°C) storage is often used to increase efficiency and viability in SIT and other types of biocontrol programmes. USDA's current research on cryopreservation and dormancy manipulation[16] could have significant impact on the design of a facility and costs of rearing in the medium to long term. Advances in this research may also permit new species to be targeted using SIT.

Perhaps someday research will allow SIT programmes to accumulate insects for release in a target area, inactivate and hold them for transport. Most importantly, shelf life of the insects may be increased dramatically. In the medium term, such research can support SIT by supporting the maintenance of strains or breeding stock. For the present, cryopreservation is limited because the development of nontoxic cryoprotectants for new species is difficult.

Other significant developments have occurred in the development of inherited lethal genes, so that a production line will not require irradiation or other types of external sterilization methods. Advances have been made in this technology by a private firm, Oxitec (Gong *et al.* 2005; Alphey 2002). By 2008, a decision should be made in the USA following the review process for permission to release Medfly and pink bollworm that have been genetically altered in this way (US Federal Register 2006). Such developments can change not only the life stage at transport, but also which species of pests might be targeted using SIT (see Section 2).

5.5 Environmental issues

5.5.1 Environmental regulations at production site

Sterile insect production facilities will be subject to local environmental regulations in the same way as any industry. Costs for permits for effluent treatment are included in the financial model (Section 7), but such costs could vary widely among different locations. The local architectural firm and construction contractor should be able to guide facility managers and investors on the requirements for both the construction phase and the operational phase, in regard to national and local standards and regulations. The use of insecticides (e.g. in the

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[16] **Cryopreservation** is the chemical and physical manipulation of cells to allow storage at liquid nitrogen temperatures. Cells are dehydrated to prevent ice crystal formation under freezing. The basic principle of cryopreservation is adequate water management using cryoprotectants that prevent solutes from reaching toxic levels. This protocol is often only viable during the embryonic stages of development for reasons of developmental plasticity, ease of permeabilization and handling logistics. Hence, if great numbers of insects need to be released quickly and/or frequently then cryopreservation will not be useful. Cryopreservation would be used to store founder strains of insects and strain replacements, which are needed in area-wide insect release programmes and research efforts. Presently, acceptable recovery from insect cryopreservation has been achieved with the NWS up to approximately 30% adult viability and with the model species *Drosophila* at a level of 40-50 percent viable adults (e.g. Leopold *et al.*, 2001; Mazur *et al.*, 1992).

Dormancy requires the precise manipulation of environmental conditions to induce dormancy artificially. This is one of the major strategies employed by insects and mites to survive harsh environmental conditions. There are two main categories, diapause and hibernal quiescense. Facultative diapause is of interest as it is often a dormant period induced by a change in environmental conditions (e.g. to endure winter). Often the major inducing signal is day length. Hibernal quiescence is mostly induced by temperature extremes. Dormancy is often associated with cold hardening – induced metabolic changes over time to enable the survival of low temperature conditions such as over wintering. Recent discoveries (Rudolf *et al.*, 1993) have found that intermittent recovery periods during cold storage have been shown to increase shelf life, possibly as toxic products can be released. Unfortunately not all insect species are capable of entering dormancy or even if they do, often it is at a life stage that is not desired for storage. Furthermore, dormancy requires that inductive cues such as the light/dark cycle are strictly adhered to, otherwise the whole stock could be deficient or not survive.

diet storage area), disinfectants or other biocides in the facility should be limited to those with proper registration in the country of use, regardless of their international acceptance.

Countries in transition may have less restrictive standards or even no standards for some of these products. In this case, the investors may wish to comply with their own country's standards or those of the probable market country or region (i.e. European Union) in order to avoid costly adjustments in the future as the country progresses in environmental protection.

5.5.2 Environmental impact assessment of SIT programmes

Environmental Impact Assessment (EIA) is used to employ decisions about use of the environment. This differs from risk assessment, which informs decisions about uncertainty. While these two methods may be used together, they are distinct. The proposed international convention to harmonize the application of EIA has never entered into force (Box 5.3), but shows what points should be covered.

Box 5.3 Points to be included in Environmental Impact Assessment (EIA)

INFORMATION TO BE INCLUDED IN THE ENVIRONMENTAL IMPACT ASSESSMENT DOCUMENTATION SHALL, AS A MINIMUM, CONTAIN IN ACCORDANCE WITH ARTICLE 4:

(a) A description of the proposed activity and its purpose;

(b) A description, where appropriate, of reasonable alternatives (for example, locational or technological) to the proposed activity and also the no-action alternative;

(c) A description of the environment likely to be significantly affected by the proposed activity and its alternatives;

(d) A description of the potential environmental impact of the proposed activity and its alternatives and an estimation of its significance;

(e) A description of mitigation measures to keep adverse environmental impact to a minimum;

(f) An explicit indication of predictive methods and underlying assumptions, as well as the relevant environmental data used;

(g) An identification of gaps in knowledge and uncertainties encountered in compiling the required information;

(h) Where appropriate, an outline for monitoring and management programmes and any plans for post-project analysis; and

(i) A non-technical summary including a visual presentation as appropriate (maps, graphs, etc.).

Source: Convention On Environmental Impact Assessment In A Transboundary Context (UN, 1991), Appendix II. This convention, also referred to as the Espoo Convention, is not in force.

As with risk assessment, EIA begins with identification of the potential hazards in order to set the limits of the study and ensure coverage of all relevant issues. The scoping stage of an EIA will be used to prepare specific terms of reference for conducting the EIA. The World Bank offers suggestions on the use of interaction matrices, flow diagrams/networks, mathematical models and field experiments to predict the potential impact of a hazard and to propose mitigative measures for any action that is deemed a viable option. This presentation of alternatives to address the initial problem distinguishes EIA from risk assessment, although some risk experts include analysis of various approaches to risk reduction. Also, EIA experts may well use risk calculations to refine the prediction of impact and mitigation.

In previous decades, any project receiving international donor funding had to fulfil some type of EIA related to the donor's domestic requirements. These EIAs generally included local experts on a consulting basis and were reviewed by the host government, in addition to the donor agency. Now national requirements for EIA have been enacted in some form in the majority of countries. While previously EIA was applied primarily to large construction projects, biodiversity impacts are increasingly considered.

In Article 14, the Convention on Biological Diversity directs its currently 190 contracting parties to develop procedures for and apply Environmental Impact Assessment to any activities that may impact on biodiversity. Although EIA is not defined in this convention, there is no indication that the CBD intended to alter the use of the concept (Glowka *et al.*, 1994).

The World Bank has guidelines on EIA for those involved in any venture (such as building a production facility) that may have an impact on the environment. The *Environmental Assessment Sourcebook* gives specific guidelines for projects involving site construction; these will relate to a sterile insect production facility as well (World Bank, 1991). The World Bank guidance has been used by many countries in the development of their national regulations regarding EIA. It is updated periodically by sections, which are available on the World Bank web site.

In an effort to maintain minimal impact on biodiversity in all its activities the World Bank publications suggest steps that should be taken to ensure effective EIA takes place. In the past, the concerns were primarily about pollution, land degradation, loss of watersheds or habitat destruction. More recent versions of the guidelines include consideration of impacts to biodiversity (World Bank, 2001). For example, the introduction of an alien species that may threaten ecosystems, habitats or species is highlighted. Here, suggested guidelines are given for procedures that should be adhered to in EIA, which can be an aid in setting up a sterile insect production facility.

Issues noted by World Bank that are relevant to a sterile insect production facility are listed below.

- Control over local resources e.g. energy, water and other consumables that have an impact on the local region.
- Construction guidelines for setting up facilities etc. in different land types, e.g. zones of unique biological diversity.
- Impact of setting and integration into local communities including suggestions for potential affected groups (e.g. members of the local community) with advice for affects such as induced development, tourism and potential compensation measures.
- Impact of new roads and access, transport of goods.
- Construction impacts; building sites are particularly susceptible to environmental disturbance; this also includes indirect impacts to be considered such as brick building.
- Waste collection and disposal systems including public health impacts, direct impacts on environment, public nuisance impacts, air issues, water issues, public cooperation,

frequency and costs of collection, recycling, siting facilities (e.g. designing a solid waste facility). Medical and toxic wastes.

- Wastewater collection treatment, reuse and disposal including the potential environmental impacts of dissolved solids of inorganic and organic matter, pathogenic micro-organisms amongst others. The World Bank publications suggest building treatment facilities in a modular fashion, extending the system as the site builds up to full capacity (Section 9).

Furthermore there are suggestions as to project alternatives in disposal, collection, recycling systems and waste monitoring. The World Bank and other international institutions recommend public consultation on new projects. Consultation can ascertain the concerns of the community where the facility will be located and of other stakeholders who were not already included in the preparation of the EIA itself.

5.6 Other regulatory concerns

5.6.1 International conventions and agreements related to sterile insects

The SIT is essentially an approach to pest control, so that the sterile insects may be viewed as plant protection products. There are international conventions on pesticides, such as the Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (FAO/UNEP, 1998), which was adopted in 1998 and entered into force in 2004. None of these agreements on plant protection products covers sterile insects, however. Instead the primary international agreements that could be related to sterile insect production and release, without specific reference to them, are:

- International Plant Protection Convention (IPPC, 1997) and its International Standards for Phytosanitary Measures (ISPMs);
- World Organisation for Animal Health (OIE) and its Animal Health Code;
- Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) under the World Trade Organization (WTO, 1995a)[17];
- Convention on Biological Diversity (CBD, 1992)[18].

The most closely related international convention is the IPPC, because presently it is the only binding agreement with reference to sterile insects or SIT (in the international standard no. 3, as discussed below). Its importance if further supported by the WTO. All 150 members of the WTO must comply with the SPS, whether or not they signed that Agreement. The essence of SPS is that national measures that may impact trade must either be (a) based on an international standard developed by one of the standard setting bodies or (b) based on the results of a risk assessment. This allows measures to be more restrictive than the international level of protection, if scientific evidence supports this stance. Because the SPS is legally binding to members of the WTO, and it names the IPPC and OIE as standard setting bodies in their areas, guidance developed by the IPPC or OIE is practically mandatory. A list of the

[17] The WTO Agreement on Technical Barriers to Trade (TBT) may cover sterile insects when the production method is clearly transgenic. This division between the SPS and TBT is not entirely clear to date. (See e.g. WTO, 1995c; Anderson and Pohl Nielsen, 2001).

18 If the sterile insects are also genetically modified (GM), then the Cartagena Protocol on Biosafety to the CBD (CBD, 2000) may be applicable in regards to international shipments.

countries that were members or contracting parties to these agreements as of 2005 appears in Annex 8.

The CBD can be interpreted as supporting SIT with its directions to its contracting parties to "*prevent the movement of alien invasive species* (which include quarantine pest species) *into a neighbour's territories as well as one's own"* (Article 4, b on jurisdictional scope regardless of where the effects occur and Article 8, h on prevention of introduction of alien invasive species). This responsibility under the CBD goes in hand with its general spirit of taking measures that do not harm the environment. The SIT is an important tool for preventing the movement of quarantine pests for which the technique has been developed.

Although this aspect of the CBD has not yet been implemented it raises the issue of whether the biological consequences of the spread of a fruit fly, for example, to other countries in a region otherwise free from this pest should require some compensation by the "polluting" country.

In the absence of more clear international guidance or obligations, countries may allow mass rearing of insect species in contained conditions, or the transit of these species through their territory, even if the species are not approved for release within the country. Rules governing release into the environment will generally more restrictive than any regulation of transport.

The IPPC is beginning to consider potential environmental impact from introduced species more intentionally by including indirect effects on plants and plant communities and impacts that arise when an introduction moves from the intended use area to another area where the species is unwanted and injurious. This guidance is a proposed supplement to the ISPM no. 11 on Pest Risk Analysis of quarantine pests (IPPC 2002b). Risk analysis is another approach to considering environmental impacts but is not the same as an EIA (Section 5.5.2). All of these international agreements indicate the use of risk assessment for decision making, except for the CBD, which is a framework convention (rather than a rule based one). The CBD does imply the use of risk assessment, however, in order to make decisions and has, in practice, increasingly turned to this method for achieving implementation (Quinlan 2001).

5.6.2 Guidelines for shipment and release of beneficial organisms

The international guidelines provided by the FAO Code of Conduct for the Import and Release of Exotic Biological Control Agents (BCAs), ISPM no. 3 (IPPC 1996a) set a precedent as a consensus document that became a legal instrument. The Code of Conduct required the producer/shipper to produce a dossier on any known/potential impacts on nontargets and/or beneficial insects as well as on production procedures and methods used to eliminate contaminants. The importing country reviews the dossier in order to make an informed decision whether or not to undertake the importation. One criterion for the decision is the seriousness of the pest problem and the probable impact of other control measures (e.g. chemical control). The Code of Conduct was the basis for national legislation or protocols, particularly in developing countries (Kairo *et al.* 2003). It was not directly related to the release of sterile insects, however, as it refers to self-replicating populations of biocontrol agents.

In 2003, consultations began on revising the Code of Conduct (Quinlan *et al.* 2003). One of the more significant recommendations that was taken up was the inclusion of other forms of beneficial organisms released intentionally for the purposes of plant protection (Quinlan *et al*. 2006). The revised ISPM no. 3 was renamed: *Guidelines for the export, shipment, import and* *release of biological control agents and other beneficial organisms* (IPPC 2005), and was endorsed in 2005 by the contracting parties to the IPPC. This international standard now specifically refers to the need to facilitate safe export, shipment, import and release of sterile insects within a pest control programme. It also acknowledges the need to mark sterile insects to distinguish them from wild individuals of the same species.

Although this standard is only relevant for species which are pests of plants, it is an important breakthrough for achieving harmonisation of national legislation and thereby facilitating international movement of sterile insects (Quinlan and Larcher 2007).

5.6.3 Regional and national laws regarding release of any exotic species

Some SIT programmes are for species that are exotic to the targeted area and have only recently been detected or established[19]. Preventative releases often consist of an exotic species that is not even found in the treated area at all. Generally, decisions regarding the release of an organism into the environment are more complicated when the species is exotic, due to the uncertainty regarding impacts of this introduction.

There are no regional or national laws that specifically address the release of sterile insects of an exotic species. Presently, governments decide under which pre-existing category to include the topic, thereby leading to the application of rules that were often developed for release of an exotic species that may survive and establish – not a sterile release.

The European Union (see Annex 8 for current members) has several directives that may impact the release of sterile insects, but that do not directly mention it. Although focused on release, these laws may also apply to import of genetic material (insects) to start a mass production colony. Most countries and regions have a separate track system for import of living organisms to be used in contained conditions or for experimentation. The mass production of such an organism that is destined for re-export is a unique situation not clearly covered by law.

These laws will need to be reconsidered for insect vectors of animal disease. The EU Directives reviewed in a Legal Impact Assessment on this matter (Fisahn 2001) concludes that European law on epizootics does not impact the rearing and release of plant pest species. The study also concludes that the release of sterile insects for the purpose of pest control will not be impacted by the restrictions to release of non-native species, since the species to be controlled is already present. The concept of “native” is not clear, however, and this may be challenged by national authorities (Fisahn 2001). Even in this scenario, approval should be forthcoming for release of the sterile insects due to the long history of safe releases in other countries (FAO/IAEA 2001a). Some member countries may prefer to assess risk and notify the public of release of sterile insects near or in a protected area (Fisahn 2001), but the risk identified is likely to be in contrast to insecticide options so should be viewed favourably.

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[19] The term “exotic” has been defined by the IPPC (ISPM no. 5 *Glossary of Phytosanitary Terms*, (IPPC 2006) in the context of the ISPM no. 3 (IPPC 1996a) as “not native to a particular country, ecosystem, or ecoarea (applied to organisms intentionally or accidentally introduced as a result of human activities)”; it is usually applied on the country level rather than by ecoarea in national legislation. With the revision of that ISPM, the term could be redefined in terms of official usage. Examples of species that are not exotic but are subject to control by SIT are tsetse fly, screwworm, codling moth and the experimental work with date moth.

The Legal Impact Assessment (Fisahn 2001) also states that Council Directive 2000/29/EEC of 8 May 2000, which allows protective measures against import of plant pests, does not apply to Medfly because that species is not listed in the relevant Annexes. Many of the candidate countries that will accede within the next few years are adopting the EU laws now rather than waiting for accession to adapt. This is a national decision for convenience rather than a requirement.

The laws and regulations regarding release of insects are, to some degree, not the responsibility of the production facility but rather the importing party. It is obvious that a basic knowledge of these regulations will improve the production company's ability to gauge markets and avoid expensive pitfalls. It should not be assumed that an importing party is familiar with all of its home country's (or transit country's) relevant laws and regulations, even when the party is part of the same government.

Section 6 Financial information for a production facility

6.1 Costs of construction of a production facility

The capital costs of a facility for SIT production cover land, building materials, construction labour and equipment costs. Land and labour are locally dependent. Building materials are common internationally priced commodities. The internal factory equipment that is not specialized for this use, such as air conditioners, compressors, power generators or equipment for waste water treatment, is sourced from national or international suppliers. Some equipment is specialized and much of this can be produced by local companies based on specifications provided from FAO/IAEA and the experience of various facilities. These items include ovipositing cages, racks and trays for mass rearing. There will be some variation in costs from place to place, but it is still practical to give general guidelines on costs, based on a simple analysis of facilities built (or under construction) over the last 15 years. This is only possible for Medfly factories, since these are the only ones for which there are data for a sufficient range of capacities. Costs for facilities to produce other species could differ considerably. Costs are shown as they were originally incurred and also inflated to 2006 prices.

Table 6.1. Recent construction and planned expansion of Medfly facilities with estimated costs and production capacities

Site	Construction from	Production capacity millions of sterile males/week	Approximate cost US$ million (cumulative for sites in stages)[a]	Approximate cost US$ million (inflated to 2006 prices)[d]
Argentina	1991	200	4.5	5.88
Chile	1992	50	2.3	2.93
El Pino stage 1	1996	500	4.2	4.93
Madeira	1996	50	2.6	3.05
W Australia pilot	1997	20	0.5	0.58
S Africa stage 1	1998	8	0.3	0.34
El Pino stage 1+2	1999	800	6.3	7.08
El Pino stage 1+2+3	2001	3500	21	22.61
Valencia, Spain	2004	560	6.8	6.99
Israel	2005	20	1.1[b]	1.12
Bahia, Brazil	2006	200	7.99[c]	7.99

[a] Some of these costing figures are not official but rather estimated from various sources.
[b] Current production is 15 to 20 million per week, but plans are to increase to 100 or even 150 million per week. Cost was estimated at $0.8 million, however there is no irradiation source on site; this would add approximately $322 000. Land also may have been unvalued, as it was already owned.
[c] Estimated cost is $4.99 million. However, land and a building provided by the government and not included in costing is valued at $3 million, making the total $7.99 million.
[d] Costs inflated using US Treasury data: http://www.gpoaccess.gov/usbudget/fy05/hist.html

Based on a regression of costs inflated to 2006 prices from Table 6.1, Figure 6.1 gives a general trend line for the cost of facilities over a range of capacities. Capital cost is most related to full capacity, but some facilities have not published full capacity, so some costings may be based on normal or current production and some will be on the facility's full capacity. There is considerable variation in the costs of small factories depending on local costs of materials and labour. A small Medfly factory (around 10 million/week) will cost around US$0.66 million and a large factory (around 500 million/week) would cost about US$7.49 million to build. The additional cost for an additional 100 million/week capacity on a large factor would be around US$0.90 million. Although the upper end of the regression is dominated by the very large El Pino facility in Guatemala, and there are no data points between production capacities of 800 and 3500 million Medfly per week at this time, the regression is relatively linear for these capital costs in the range above 500 million/week.

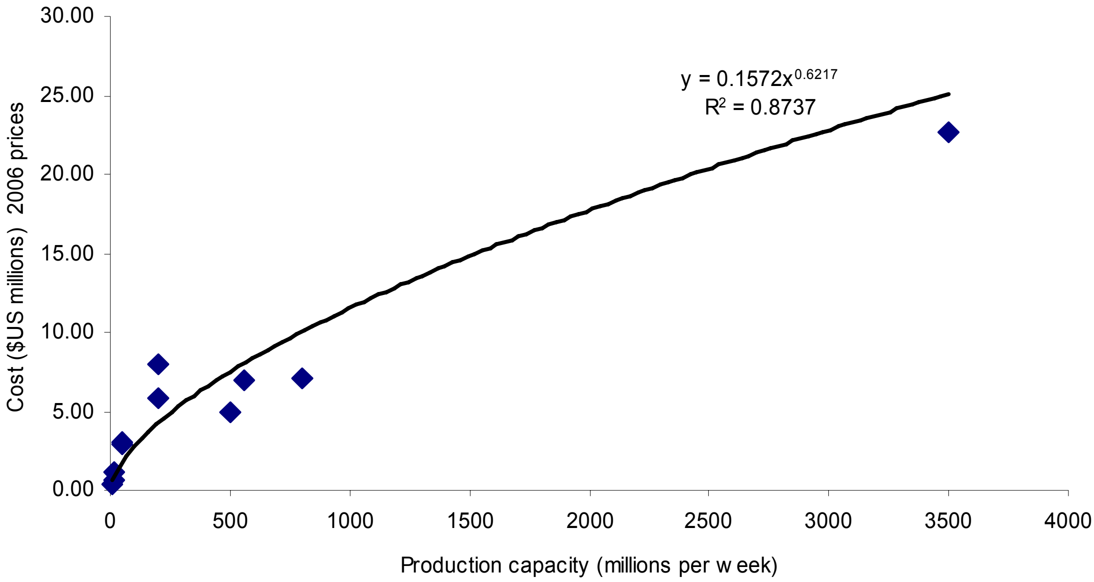

FIG. 6.1. Capital costs of sterile Mediterranean fruit fly facilities built between 1991 and 2006. Adjusted for inflation using GDP (chained) Price Index (US Treasury, May 2006). If not adjusted for inflation, R^2= 0.8752.

The intuitive conclusion that significant savings will be achieved from "economies of scale" is not particularly significant for the larger facilities in which modules are preferred over larger single units for increased production. Some savings gained by facilities with larger capacity arise primarily from the operational "fixed costs" such as administration or sales and marketing. Research and development (R&D) may also provide some economy of scale, as presented in Section 7, although larger colonies may present different research and development challenges. Larger capacity facilities face larger costs for high cost items such as effluent treatment or the physical separation of modules. This separation provides some insurance against biological risks, however, as discussed in Sections 3.5.5 and 5.1.3.

Therefore, Figure 6.1 gives a general guide to capital costs for a sterile Medfly production facility. Where a proposed new facility costing is markedly different from this, which may occur due to local circumstances of land prices, labour rates or regulatory costs related to building codes, the reasons should be very clearly identified and considered. It is interesting to note, for example, that a facility proposed for construction in Hawaii would have produced 550 million sterile Medfly males/week but at a construction cost of $60 million

(USDA/APHIS, 2006). This is well outside the normal range of costs and the plan was rejected.

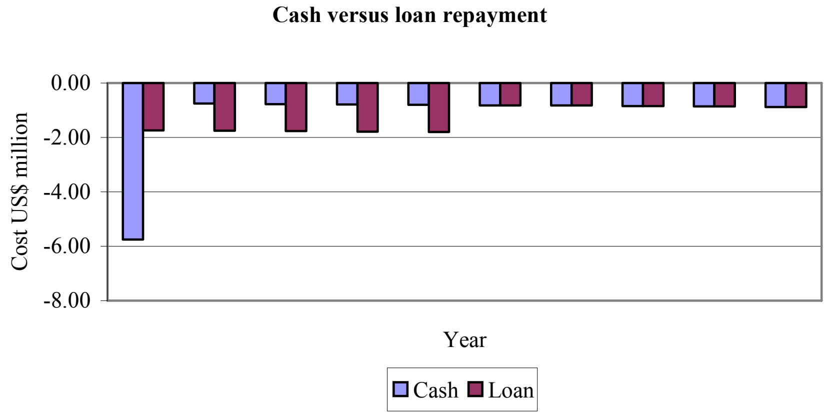

FIG. 6.2. Cash versus loan payment schedule
Based on an example including principal repayment (US$5 million), interest (5%), opportunity cost of capital (set equal to interest rate) and depreciation (10 years) over 10 years with 5-year repayment.

If funding were arranged through a loan the impact on cash flow would be reduced and the capital cost would be spread over many years as a combination of interest payments, principal repayments and depreciation allowances (Table 6.2, Figure 6.2). The effect of using cash versus a loan on the overall cost of production depends on two main factors: the terms for the relative values of the interest rates on a loan, and the opportunity costs of other possible cash investments available at the time. In a competitive market these two values (interest rate and opportunity cost) should be similar.

Table 6.2. Example distribution of costs for cash or loan options, assuming opportunity costs and interest rates are similar

Item	**Unit**	**Rate**	**Year**										
			1	2	3	4	5	6	7	8	9	10	**10-yr total**
Cash													
Capital outlay	US$ million	5	5.00										**5.00**
Opportunity cost	% foregone	5	0.25	0.26	0.28	0.29	0.30	0.32	0.34	0.35	0.37	0.39	**3.14**
Depreciation	Years, linear	10	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	**5.00**
Total cost			**-5.75**	**-0.76**	**-0.78**	**-0.79**	**-0.80**	**-0.82**	**-0.84**	**-0.85**	**-0.87**	**-0.89**	**-13.14**
Loan													
Principal repayment	Years, linear	5	1.00	1.00	1.00	1.00	1.00						**5.00**
Interest cost	% on principal	5	0.20	0.15	0.10	0.05							**0.50**
Opportunity cost	% foregone	5	0.05	0.11	0.18	0.24	0.30	0.32	0.34	0.35	0.37	0.39	**2.64**
Depreciation	Years, linear	10	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	**5.00**
Total cost			**-1.75**	**-1.76**	**-1.78**	**-1.79**	**-1.80**	**-0.82**	**-0.84**	**-0.85**	**-0.87**	**-0.89**	**-13.14**

Depreciation is also a significant issue in determining costs. Depreciation will depend on the type of construction for the building. It should reflect the cost of ongoing maintenance and the replacement cost amortized over the depreciation period. The same should be true for equipment within the buildings, with the depreciation period relative to expected life of individual pieces. Using a range of depreciation periods for each item can create a very complex planning schedule, however, and it is often all combined into a common time period in the expectation that early and late items will cancel out. The large Guatemala facility (El Pino) uses a ten-year depreciation schedule for overall capital costs. This is the approach chosen for this report.

Other costs that could be considered as part of the initial capital development stage include creation of human capital through training programmes. The final costs could include the establishment of insect delivery and release, field detection/monitoring systems and quarantine infrastructure, if these are part of the service provided by the production facility. The examples provided are just one way to consider the various components.

6.2 Costs of operation of a production facility

Operational costs comprise fixed and variable costs. Fixed costs are not directly related to the level of production (such as repayment on capital costs, administration and permanent employees, communications, utilities, research and development, base stock of insects, waste insects not needed for release, insurance). Variable costs are directly related to production (rearing diet, fixed term production employees, transport, quality control, etc.).

In general sterile insect rearing is a continuous process with new batches of production starting every few days throughout the year or over a particular season. The number of sterile insects produced may change over the season as the demand in field operations changes. Each of the continuously developing batches of insects has a proportional share of the daily fixed and variable costs that depends on the number and size of all the other batches in the pipeline. So, the actual cost for a batch of a particular size varies from batch to batch as production rises and falls, but would be constant if the size and interval of the batches were constant.

A practical way to calculate costs would be to use averages over time intervals that are much longer than the development time for a single batch. This evens out rises and falls in production over short intervals. So for an individual batch production run of three weeks, costs might be calculated over a three-month period or longer. In this case, all costs for a quarter year (fixed and variable) would be apportioned to the total *delivered* production for that quarter. In setting prices, an estimated delivered production volume and the estimated total costs for the period would form some basis for costing and pricing insects per unit (for example, per million sterilized male pupae delivered for release).

It is important to note that if costing is based on time periods that are shorter than individual production runs there is a danger that costs per unit are incorrectly estimated at the start and end of a season's run and during non-producing periods (if production is not continued throughout the year). Table 6.3 illustrates the difference in weekly, average weekly and average quarterly cost per unit. The average cost per million in this theoretical run is made up of a weekly share of a quarterly fixed cost based on capacity, and weekly variable costs calculated at one-third of the total variable cost per batch (since there is assumed to be a three week production cycle) for each batch under way. The average quarterly cost per million is US$375, the average weekly cost once the first cycle is complete is US$363, and the weekly cost per million against all cumulative costs from the previous sale ranges from US$144 to US$940 per million. When a facility is working with hundreds of millions, weekly pricing could lead to shortfalls or overpricing.

Assuming relatively constant production and production at near full capacity, a very large facility such as El Pino, Guatemala, can produce sterile Medfly at a cost of around

US$220/million sterile male pupae (2001 figures)[20]. This cost includes depreciation but not capital costs – therefore this is not for comparison with other, private facilities. It is based on production using genetically linked sexing strains, so that costs later in the production process are less than for unsexed Medfly. In comparison, New World screwworm (NWS) costs are approximately US$1900/million sterile pupae (unsexed) at the Mexico facility. Sterile codling moth costs are approximately US$8500/million (unsexed) at the Canada facility.

Table 6.3. Example of weekly and quarterly cost estimates for a production run of four batches starting weekly, running three weeks, with a one-week restart interval with no production

Impact of costing sterile insect production by week vs. quarterly

	Week	1	2	3	4	5	6	7	8	9	10	11	12	13	Total (in production)
Batch	#1	50	50	50		50	50	50		50	50	50			**450**
(number in	#2		50	50	50		50	50	50		50	50	50		**450**
production)	#3			50	50	50		50	50	50		50	50	50	**450**
	#4			50	50	50		50	50	50		50	50	50	**450**
Resulting production levels:				50	50	100		50	50	100		50	50	100	**600**
Fixed costs	150	6 923	6 923	6 923	6 923	6 923	6 923	6 923	6 923	6 923	6 923	6 923	6 923	6 923	**90 000**
Variable costs	225 per million	3 750	7 500	15 000	11 250	11 250	7 500	15 000	11 250	11 250	7 500	15 000	11 250	7 500	**135 000**
Total weekly cost		10 673	14 423	21 923	18 173	18 173	14 423	21 923	18 173	18 173	14 423	21 923	18 173	14 423	
									Total costs over 13 weeks						$225 000
									or over one quarter						
Cost/million/week				940	363	182		727	363	182		727	363	1 445	**$363** average
Costs/million/week estimated over one quarter															**$375** average

These examples of costs should not to be confused with the price of the sterile insects. As shown, a sterile insect facility that has either been already running for some time or that never reflected capital costs (possibly because it is selling exclusively to those who put up the capital, such as a government that did not intend to sell production) will have lower costs, but may be limited in its mandate to sell to others. With the development of commercial sterile insect production facilities, facilities with the advantage of full or partial funding from governments would distort the global market if they continued to sell at prices based on marginal costs and they could therefore produce disincentives to the private sector.

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[20] There is little historical data on actual costs, but Liedo *et al.*, 1990, stated that the average weekly production over ten years at the Metapa plant (1980-1990) produced over 500 million sterile Medfly per week at costs averaging between US$95 to US$175 per million. A more recent document suggests that El Pino can produce one million sterile males at US$101, whereas Metapa's Medfly would cost US$379. This could be possible if the other figures are correct: El Pino is now producing 3,500 million sterile male per week and the total facility to this point cost $22.6 million in capital costs (at 2006 $ values). The lower costs per million figure might not include recovery of capital costs so that the higher figure is more realistic in today's terms (USDA/APHIS, 2006).

6.3 Pricing of the product

There are two basic principles for pricing sterile insects, cost-based and value-based. There is a considerable range of options, but relatively few precedents. The most common arrangement since the inception of the SIT has been government sponsored production facilities whose costs have been incorporated internally into insect management budgets. In some cases grower groups or other governments have shared in the costs of the programmes, but not explicitly through the purchase of sterile insects or other specific services. There are no examples of value-based pricing for sterile insects yet, in which the purchaser pays a price related to the costs saved and value added to the product through using SIT, although this happens in the sale of biocontrol and pollinating insects in protected (greenhouse) crops.

Financial models for production facilities reflect a range of levels of management and risk sharing. The list below indicates the many possibilities:

(1) government funded insect control programme with SIT facility as an internal cost; no explicit product pricing; value is a free gain to recipients, but in competition with other government programmes demanding expenditure;

(2) government funded insect control programme with an interagency or interdepartmental SIT facility; price paid as an inter- or intra-agency transfer, at cost, including some agreed upon agency overhead rate, which may be dependent on how the facility was financed;

(3) privately funded insect control programme with SIT facility as an internal cost; no explicit product pricing; added value reverts to the producer group sponsoring the programme;

(4) control programme constructs SIT facility and contracts the management at a fixed fee; no explicit pricing based on production; this reduces uncertainties and long-term commitments on management costs and may yield efficiency gains depending on management incentives;

(5) control programme constructs SIT facility and contracts the management; pays through price of sterile insects produced on contract, in which the price may reflect operating costs only, or could include a discount to reflect a rent to pay back on the investment in the facility by the operating managers;

(6) control programme contracts a company to construct a facility and provide sterile insects; pricing could be based on service provision at specified capacity (rather than actual production) for a period of years, and would reflect the relatively low risk taken by the contractor;

(7) independent SIT facility sells products to control programmes at a commercial rate that includes operating costs, recovery of capital costs and a profit level set to cover an acceptable return on the investment and risk (this could be subject to a limit imposed by the price of competing control alternatives);

(8) independent SIT facility sells products to control programmes at a commercial rate that reflects the value of control delivered compared to competitive alternatives (this may include savings in insecticides, premium value from reduced pesticide residues and access to premium markets due to pest and/or pesticide free status, but is unlikely to include less tangible environmental values resulting from SIT such as reduced poisoning of wildlife, contamination of water or improved human health that is hard to capture in direct market terms).

A business selling sterile insects offers insects at a stated quality, location and time. Its customers should expect to pay for:

- the direct operating costs to produce to those specifications;
- a pro rata proportion of the capital costs needed to provide facilities for that production;
- a return on capital investment;
- a return on intellectual investment (for example, research on efficient production techniques);
- a return on risk taking (for example, for anticipating capacity, for providing flexible production to meet changing specifications, etc.) that is determined by the degree of speculation over capacity, quality, and other specifications;
- a profit related to the competitive performance of alternative management options (for example, if pesticide control is much more expensive than SIT, or precludes entry in some markets, then some of that additional benefit may be sought by the sterile insect supplier) and competition from alternative SIT suppliers.

In addition, there will be value added by the use of SIT, which will be difficult to recover fully due to relatively intangible environmental values, and due to some inevitable "free riders" in an area-wide control programme.

The capital cost is a function of capacity, rather than actual production. Operating costs have an essentially fixed management component related to capacity and a variable cost related to production during a particular time period. Pricing must also take into account capital costs during off-peak production periods.

Financial models cover the range from a fully internalized production system to one in which investment in the SIT capacity is entirely speculative and customers simply buy as and when needed with no commitment to the production facility. The latter is unlikely to occur because of the long time commitment to implement an SIT programme and the difficulty of transferring from one supplier to another (both technically, in terms of the insect strain supplied and logistically, since new transports links would need to be arranged). The most likely commercial arrangement would be for a long-term contract to supply an agreed number of insects on a predetermined price formula, probably coupled with further sales as opportunities arise after some initial foundation contracts to supply have been secured. There may be options for early customers to seek price reductions when new buyers are found to share capital costs.

To keep prices lower SIT buyers should:

- set very clear specifications on quality, location, time and numbers to be supplied so that fixed costs associated with overcapacity are kept down;
- share some risks with suppliers (for example, accepting to pay a fixed share of capital costs to ensure a certain capacity).

Conversely, sellers can increase their returns by accepting risk (through greater investment in facilities and efficient production operations). These risks can be offset by efforts to extend their market to other locations and products.

There are a number of issues of potential disagreement that could affect pricing and which may need to be considered in a pricing formula:

- rate of depreciation on capital;
- level of capacity in which to invest;
- appropriate shares of fixed costs to attribute when several markets share production, especially where new markets open up after the initial investment;
- estimates of future sales to alternative markets which affect decisions on capacity;
- estimates of transportability of sterile insects to alternative markets at specified quality and time;
- ability to improve efficiency on production;
- ownership of intellectual property resulting in efficiency gains;
- boundaries and measures of performance (for example, is quality measured at the factory or in the field at some point after delivery to buyer, and what is the appropriate measure of quality?);
- provision of additional related services, such as in field monitoring of performance;
- share of any benefits arising from comparison of SIT product performance to alternative controls (or more generally, is the supplier providing simply sterile insects or a service that results in a pest-free, or reduced-pest, environment?);
- responsibility in the event of failure in control.

Some specific relevant examples of pricing:

Medfly SIT. The USDA invested in a fruit fly factory at El Pino, Guatemala, that is managed privately under contract. The US Governments paid all capital costs. The remaining costs are paid on a contracted level of capacity (US$ per million flies expected to be produced and delivered) on the basis of an agreed account of fixed and variable costs associated with production at that level for an agreed period and regularly audited and reviewed. Efficiency gains are passed on to the buyer. Occasional smaller scale buyers in other markets (for example, Israel) pay similar prices. This is a typical example of cost-based pricing.

Pollinating bumble-bees in protected crops. Bumble-bees are used to pollinate many vegetable crops grown in glass or plastic houses in Europe. The bees are provided as part of a service, which guarantees a certain level of pollination in a space. So contracts are per unit area for a specified period of time, rather than for a specific number of bumble-bee-days. During the contract the suppliers deliver hives, monitor bumble-bee populations and activity and replace, augment or remove hives as needed to efficiently achieve the contracted level of pollination. Prices are based on the value of the service compared to hand or natural pollination. Because the bees are provided in well-defined environments to individual businesses and the value is directly measurable, value-based pricing is very practical and profitable.

Section 7 Summary of feasibility using a financial model

The key question for any investor will be the probability of achieving, at minimum, some set rate of return. Using information from sterile Medfly production facilities in operation, a model was developed to show the relationship between costs, level of production and the price of sale.

This financial model is based on construction of a fixed capacity factory for Medfly, with loan capital. It was developed using the software Excel/Crystal Ball™ to show a prediction of the flow of money for the entire venture over the first ten years, starting with the year of construction. The profit level was set in the model, in coordination with the competitive price, in this case an average of US$378 per million sterile male Medfly sold per week (with prices varying according to costs). Under these assumptions, the forecast for achieving a 10 percent profit over a 10-year period is very high. The model can be used to demonstrate the probability of achieving other levels of profit, but either the costs or the price per million sterile flies sold must be varied to match the change in profit.

The assumptions and results will differ greatly by species. Presently, such information is not systematically collected at each production facility, although similar information is likely to exist. In order to test new versions of this model, which seems especially useful with the involvement of private sector, pricing must become increasingly related to real costs. Therefore real costs must be tracked, possibly using a harmonized template to facilitate comparison and provide transparency.

7.1 Capital outlay

The model shows a theoretical facility with a sales target of nearly 972 million sterile male Medfly per week, assuming a proportion of 88 percent use of the full projected design capacity. (Each variable in green in Figure 7.4 is the probability weighted mean from the range of values used in the analysis. The actual value used in the model is to ten decimal points – closer to 88.333 percent for a sales target of 971.67 million – but for convenience these figures are rounded in the explanatory text.)

The capital cost of this facility is taken from the regression formula on capital costs of major Medfly factories built in the past ten years (see Section 6). Interest on the initial loan is set at 10 percent APR (but could vary from 7 to 15 percent). The repayment of the loan is calculated for the total loan (principal and interest) to be paid off 5 years from set up. The model allows for other periods of repayment if preferred.

Also shown is the interest on costs on capital – interest on the previous year's outstanding loan, after payment for that year. The opportunity cost is then worked out on interest and principal accumulated. For this model, depreciation has been fixed each year at 10 percent, to reach zero value after ten years.

7.2 Fixed costs

Fixed costs are those that do not vary in relation to sales, although the capacity of the facility does affect the values. For example, administration costs were calculated using labour costs from the collective model (US$191 000/year) with an adjustment for inflation of 6 percent.

(Inflation on other costs is not shown as it is assumed that it matches the inflation on prices. Labour is assumed to be rising at a faster rate, in this scenario.)

Utilities and communications (US$161 000/year) remain constant to the capacity, regardless of the production achieved in any given year. Insurance and security (loss and liability) and security services are set as 1 percent of the capital value based on the actual figures from operating facilities.

Research and development (R&D) (US$250 000/year), quality management (US$107 000/year), effluent management (US$72 000/year) and sales and promotion (US$89 000/year) are all shown as constant values, with the point of view that such activities must be carried out from the time of construction, even before production begins. The R&D is not always included in facility budgets, but is a necessary component. It is included, even if income may be collected from sources other than sales (e.g. from government funds for research).

7.3 Variable costs

All variable costs are based on the number of flies sold multiplied by 52 weeks to give an annual figure. Insect diet, which increases in cost until year 4 (when at full production) is then fixed at US$5.053 million/year. General supplies and transportation follow the same trend, levelling off at just over US$2.526 million/year and US$505 000/year, respectively.

Labour costs are also shown, with an option to increase at a rate greater than general inflation, since this is a cost more subject to local conditions than other internationally priced inputs. If a labour inflator is set, it will appear in both the administration line in fixed costs and in the labour line under variable costs.

From the variables shown, a value of the total costs of the entire facility for the model factory can be calculated – both on a yearly level, and based on the average costs over the 10-year period on which the frequency distribution charts are set. Once the annual net profit on sales has been calculated (see model) the cumulative income (profit minus costs) can be shown. In this case, the model predicts that the facility will become profitable in the sixth year. The 10-year prediction of cumulative income, including profit, is US$9.673 million.

7.4 Variable values

Capacity is set at 1100 million/week and the sales target is 88 percent of the capacity (972 million sterile males/week). Interest rates and opportunity costs were set at 10 percent, labour inflation rate at 6 percent above general inflation and the planned profit on sales rate has been set at 10 percent, which gives a mean proposed price of US$386/million sterile males selling price with an average production cost of US$351/million. However, the maximum competitive price/million is set at US$375, which was the price used by El Pino at the time the model was developed in 2002 (this figure is changing over time, however, so that other sections of this report may choose other values). If that were the maximum market price that could be achieved, in practice it would not be possible to achieve the target profit of 10%. This is reflected in simulation runs of the model in which some variables have different values based on probability distributions, shown in the next section.

7.5 Frequency charts

The first Frequency Chart (Figure 7.1) describes the frequency of potential product costs based on the 10-year average cost (not the annual costs). The model shows a normal frequency distribution of predicted production costs with a mean of US$362/million males. The chart is made up of bars showing the number of times each cost results. The sum of the total frequency adds up to one. If the cost bands were narrower, the number of times that the average product cost actually occurred would be greater than the 3 percent (approximate) of the time for the cost bands shown here.

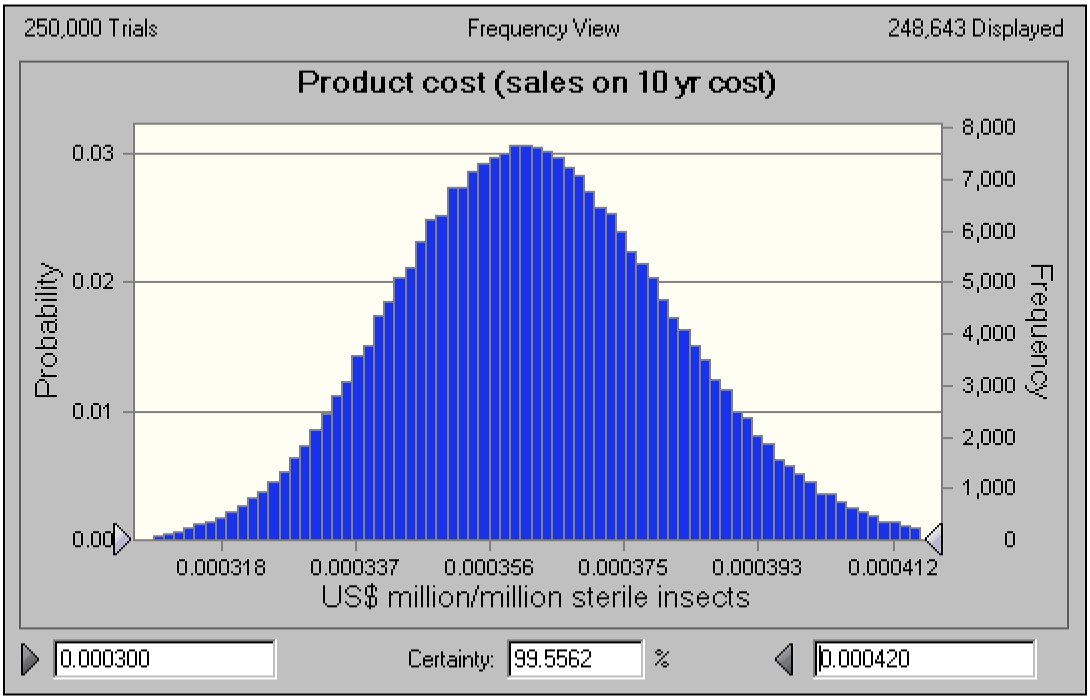

FIG. 7.1 The frequency of different product costs, showing the majority of cases to fall around US$362/million.

The other Frequency Chart, Figure 7.2, shows the range of expected profit given all other assumptions described above. This assumes that the price charged would include a 10% profit above the production cost, but with a cap on prices set by competition at $375/million flies in some cases the profit would be less than 10% to remain competitive. There is also some proportion of cases in which the predicted range of production costs might exceed $375/million and so flies would be sold at a loss.

Because there is a possibility of the costs being higher than the expected competitive selling price used in this model (US$375/million males) on some occasions, the certainty range is set at zero to infinity, with the idea that zero – the point at which the business begins to lose money – is the critical minimum. This shows that 72% of the model runs result in profits, while 28% give a loss. The lowest acceptable point could be set at some other number, such as US$1 million, if this were the lowest value acceptable to investors or management. This would result in a lower probability, all else being equal.

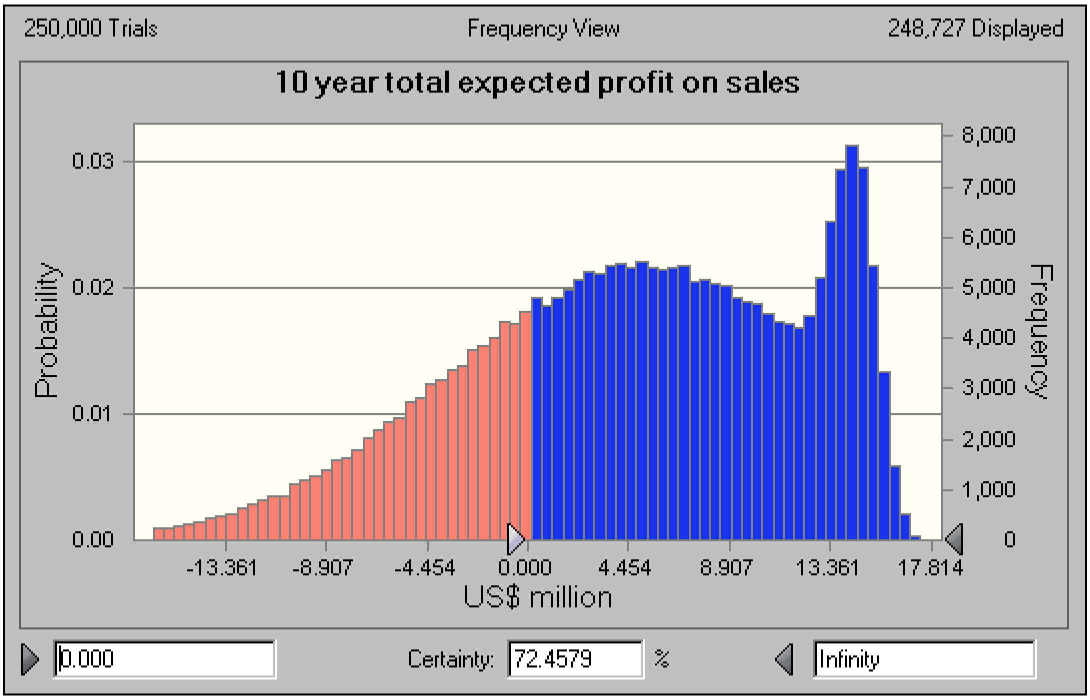

FIG. 7.2. The frequency of different levels of cumulative profit over 10 years for the given scenario, showing the mean as around US$4.5 million, but some incidences of loss.

The long tail of the distribution of profits is skewed to lower profit than a higher profit, because of the limitations set by the maximum competitive price within this set of runs. In other words, the curve is skewed to extend further to the left, and into the "red", even though the greatest number of runs fell close to the mean cumulative profit of approximately US$4.5 million over the 10-year period.

These simulations were carried out using Crystal Ball™ with 250 000 runs using the distributions of values for the variables, with pre-set uncertainty ranges. Because each of the values includes some uncertainty, this is a way to predict the probable outcome with all factors included. For business plans, it takes the place of "contingencies" that relate to uncertainty but does not attempt to quantify its range.

7.6 Sensitivity chart

The Sensitivity Chart (Figure 7.3) shows the proportional sources of uncertainty for the overall results. In Figure 7.4, the figures shown in green all have uncertainty distributions of their own. A single figure is used, but in reality the line item is composed of a distribution of values rather than a single number. These nine factors, which appear in the chart below, together constitute the overall uncertainty of the final cumulative 10-year profit figure.

The Sensitivity Chart feature in Crystal Ball™ provides one with the ability quickly and easily to judge the influence each forecast cell has on a particular output cell. In this report the output cell featured is the product cost. During a simulation, Crystal Ball™ ranks the assumptions according to their importance to each forecast cell. The Sensitivity Chart displays these rankings as a bar chart, indicating which assumptions are the most important or least important ones in the model. The Sensitivity Chart displays the sensitivity rankings of the assumptions in the simulation. The variable inputs are listed on the left side, starting with the assumption with the highest sensitivity. The bar chart of values indicates the direction of influence. For example, higher insect diet costs increase overall costs and lower profits (so bar to the left), while higher proportional use of the facility, the sales target value, reduces costs, increases profits (so the bar is to the right). The percentage contribution to variance of the respective assumption is shown in each bar.

The assumption with the highest sensitivity ranking can be considered the most important one in the model. It allows the user the opportunity to investigate this assumption further in the hope of reducing its uncertainty, and therefore its effect on the target forecast. The assumption with the lowest sensitivity ranking is the least important one in the model (of those investigated). The effect of this assumption on the target forecast is not as great as the others and, in some cases, could be ignored or discarded altogether.

The sales target is the proportion of the full capacity that is actually producing product for sale at any given time. If a facility has eight modules, for example, then at any given time one may be used to just start a batch and therefore not be producing for a few weeks, or it may be in maintenance or experiencing some problem. The lower the sales target, the higher the amount of unused capacity. This is a theoretical figure, but based on practical experience of operators of facilities. It shows the value of the modular approach, despite its removal of the "economy of scale". If only two modules exist and one is closed down, then the sales target drops to 50 percent rather than approximately 88 percent for one of eight modules.

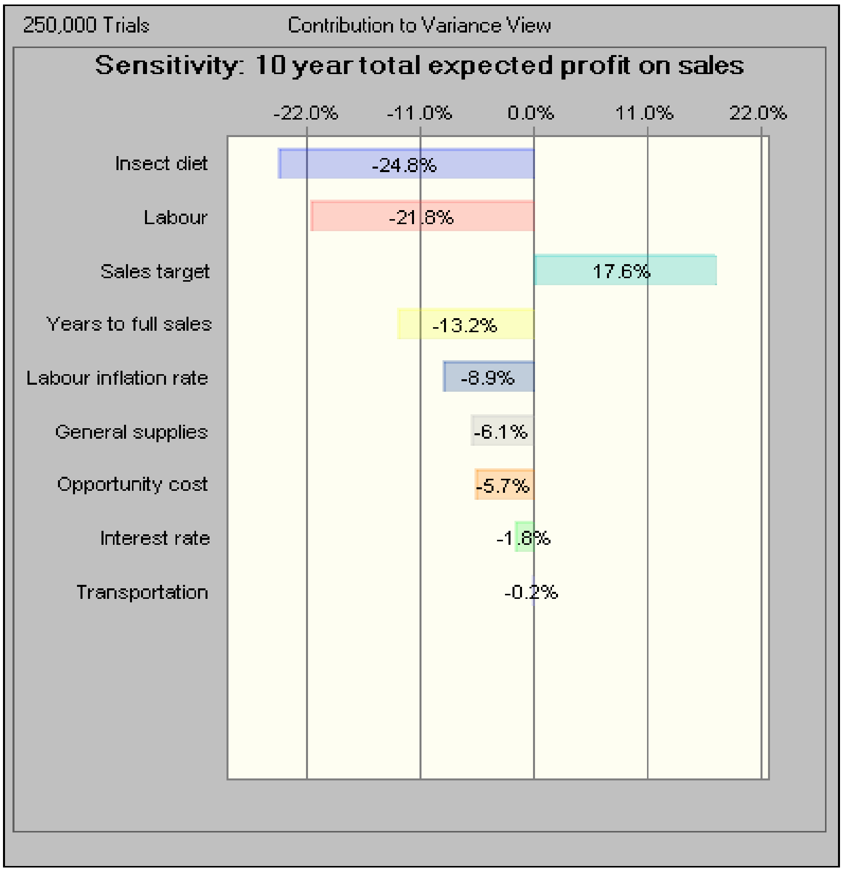

FIG. 7.3. The relative sources of uncertainty for the total outcome of the model.

It is almost impossible for 100 percent of the capacity of any facility to be providing product to sell over any length of time. Since the lower the sales target is, the fewer sterile insects are actually sold, this decreases the profit (thus the negative relationship to the other factors shown.) The bar chart shows that a labour inflation rate, above and beyond the overall inflation that may arise for other factors, has a similar impact to the sales target.

Of those investigated, the remaining five factors contributing to uncertainty are also significant but, relative to each other, much less so than these first four described (insect diet, labour, sales target and labour inflation).

7.7 Limitations of the model

There are various limitations to this model, the greatest of which is the lack of access to data from Medfly facilities and the lack of data for other species. Inflation/deflation has not been accounted for in either costs or prices, except for labour/wage rates above inflation (entered as a variable) to allow for this exceeding general inflation in some cases.

The model is a useful planning tool, but cannot take the place of more detailed and shorter time frame accounting procedures and reports. The model may be useful for periodic checks of what is actually happening in comparison to what was projected for the 10-year period. Once at full production, values will appear to be fixed unless more modules are built and if this happens, the financial model will have to be reviewed.

The presentation of any model in a report limits it to one set of data and assumptions. Using the model, other runs can be made using the Crystal Ball™ program, (it can run alone in Excel, but does not demonstrate the stochastic element, since it only runs on the expected values in the variable list). Other example runs could be based on a costs+profits basis, or against a different competitive price, or simply at cost. Once more precise local costs are known for the proposed venture, then the affected variables can be entered into the model and run again. This model is tested against the case of Slovakia using various scenarios for the proposed full-scale Medfly production facility's operating budget (see Annex 1).

Breakthroughs in the production of SIT that cannot be predicted may require adjustments to the model. The model is robust, however, as the dynamics of the insect populations are unlikely to change significantly (e.g. development rate, food requirements). It can be used for mid- to long-term planning or to inform present decisions by showing the impact of various changes, such as a reduction in the costs of labour or insect diet.

23/05/2006

This financial model is based on construction of a fixed capacity factory for Medfly, with loan capital.
Inflation/deflation not included in either costs or prices, except for labour/wage rates (enter as a variable) to allow for these exceeding general inflation in some cases.

Item	**Year** 1	2	3	4	5	6	7	8	9	10	10-yr total
Production											
Sales (millions/week average per year)	0	486	729	972	972	972	972	972	972	972	**8016**
Capital	All values below are in US$ million										
Capital outlay	*12.226*										***12.226***
Credit line interest cost		0.229	0.342	0.178	0.000	0.003	0.000	0.000	0.000	0.000	**0.752**
Principal repayment		3.057	3.057	3.057	3.057	0.000	0.000	0.000	0.000	0.000	**12.226**
Interest cost on capital outlay		1.263	0.948	0.632	0.316	0.000	0.000	0.000	0.000	0.000	**3.158**
Opportunity cost		0.446	0.859	1.240	1.588	1.588	1.588	1.588	1.588	1.588	**12.076**
Depreciation	1.223	1.223	1.223	1.223	1.223	1.223	1.223	1.223	1.223	1.223	**12.226**
Fixed											
Administration	0.191	0.203	0.215	0.229	0.244	0.259	0.275	0.293	0.311	0.331	**2.551**
Utilities and communications	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	**1.606**
Insurance/security (loss & liability)	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	**1.223**
Research and development	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	**2.503**
Quality management	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	**1.073**
Effluent management	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	**0.715**
Sales/promotion	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	**0.894**
Variable											
Insect diet	0.000	2.526	3.790	5.053	5.053	5.053	5.053	5.053	5.053	5.053	**41.685**
General supplies	0.000	1.263	1.895	2.526	2.526	2.526	2.526	2.526	2.526	2.526	**20.842**
Labour	0.000	1.522	2.427	3.441	3.659	3.891	4.137	4.400	4.678	4.974	**33.130**
Transportation	0.000	0.253	0.379	0.505	0.505	0.505	0.505	0.505	0.505	0.505	**4.168**
Total cost	**-2.214**	**-12.785**	**-15.935**	**-18.885**	**-18.972**	**-15.849**	**-16.109**	**-16.389**	**-16.686**	**-17.002**	**-150.827**
Income											
Sales at annual cost	*0.000*	*12.785*	*15.935*	*18.885*	*18.972*	*15.849*	*16.109*	*16.389*	*16.686*	*17.002*	***148.613***
Sales at 10-year average cost	*0.000*	*9.121*	*13.681*	*18.242*	*18.242*	*18.242*	*18.242*	*18.242*	*18.242*	*18.242*	***150.493***
Sales at 10-year average cost+profit	**0.000**	**9.474**	**14.211**	**18.948**	**18.948**	**18.948**	**18.948**	**18.948**	**18.948**	**18.948**	**156.317**
Cumulative income (inc profit) minus costs	***-2.214***	***-5.526***	***-7.251***	***-7.188***	***-7.212***	***-4.114***	***-1.276***	***1.283***	***3.544***	***5.489***	**5.489**
Profit											
Annual net on sales	**-2.214**	**-3.311**	**-1.725**	**0.062**	**-0.024**	**3.098**	**2.838**	**2.559**	**2.261**	**1.945**	**5.489**
Cumulative proportion on expenditure	*-1.000*	*-0.368*	*-0.234*	*-0.144*	*-0.105*	*-0.049*	*-0.013*	*0.011*	*0.026*	*0.036*	*0.036*
Net present value (10 years) on profits $mn	**1.201**										
Internal rate of return (IRR)	**10%**										

FIG. 7.4. Sterile Medfly production facility financial planning model - ten-year period

Variables values to set		Fixed costs (annual per capacity)		Variable costs (per 1 mi	
Capacity (millions/week)	**1100**	Administration	**0.191**	Insect diet	**0.000100**
Sales target proportion of capacity	**0.88**	Utilities and communications	**0.161**	General supplies	**0.000050**
Years to full sales	**4**	Insurance/security (loss & liability)	**0.122**	Labour	**0.000057**
Interest rate	**0.10**	Research and development	**0.250**	Transportation	**0.000010**
Opportunity cost rate	**0.10**	Quality management	**0.107**		
Repayment period on loan years	**5**	Effluent management	**0.072**	*Subtotal*	*0.000217*
Depreciation period in years	**10**	Sales/promotion	**0.089**		
Labour inflation rate	**0.06**			**Product cost and price**	
Planned profit on sales rate	**0.10**	*Subtotal*	*0.992*	On average 10 year sales/total cost	**0.000361**
Maximum competitive price/million	**0.000375**			Proposed price/million	**0.000397**
Discount rate	**0.07**				

This model was developed by Prof JD Mumford, in consultation with MM Quinlan and Dr JD Knight, with appreciation for input by Dr Adrian Leach. Values in the two blue cells are output values for an individual model run and would be different in each of the 250 000 model simulation runs

FIG. 7.4.(Continued) Sterile Medfly production facility financial planning model - ten-year period

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Section 8 Conclusions

The sterile insect technique (SIT) has been applied against plant and animal pests and vectors of animal and human disease for over 50 years. This experience has been successful for the eradication of many important pests, such as the Mediterranean fruit fly from Chile; the melon fly from Okinawa, Japan; the New World Screwworm from the USA, Central America and Libya; and the tsetse fly from Zanzibar, Tanzania. Eradications such as these were the original purpose intended from the development of the technique. More recently SIT has also been successfully applied for the purpose of suppression, containment and prevention (preventative barrier releases), such as the preventative release of Medfly in Los Angeles area of California or the New World Screwworm (NWS) release along the Darien Isthmus in Panama. While SIT is a proven, effective and efficient form of insect pest control, in all these cases SIT constitutes one important component within a wider system of control measures (an area-wide integrated pest management scheme) and is suitable only for certain pest species.

The technology has not yet been taken advantage of for many of the species that appear to be suitable to control using SIT. The uptake of SIT in any particular case is affected by farmer reliance on pesticides and mistrust of the results of less dramatic methods, as well as the overall cohesion and organization of producers. The presence of “free riders” in the treatment area, or of extensive non-commercial hosts, also may affect other farmer’s desire to pay. There are new driving forces, however, that may lead to a significant increase in the use of SIT. Paramount among these is the worldwide desire to apply less pesticide in the environment and to purchase produce without harmful residues. The lack of consistent or nearby supplies of sterile insects continues to limit the use of SIT in some situations, but, in the case of Medfly, is being alleviated by input from new private and public/private production facilities.

As the knowledge and technology for insect mass rearing improves – including use of new materials for diets and in some cases automation of labour intensive steps – the production of sterile insects becomes more cost effective. One of the greatest developments for cost savings in shipping and release is the Medfly genetic sexing strains in which large scale separation of the sexes is possible allowing male-only sterile fly releases. The FAO/IAEA Agriculture and Biotechnology Laboratory, Seibersdorf, has led this work in collaboration with government and university research centres throughout the world. SIT programmes with other target pests, for example the *Anastrepha* genus, will benefit greatly once this same improvement is developed for male only releases in those cases as well.

It is easy to establish, even without cohesive market data, that demand for the well known SIT target species exceeds the production on a global level. This is particularly true for the principal tsetse species. Other sterile insects that will undoubtedly be in great demand once the supply is in place include the Old World Screwworm, codling moth, the South American fruit fly and possibly the olive fly. Because methyl bromide (MB) is becoming less available, the option of SIT will be even more important for control of post harvest pests that have traditionally been treated with this broad spectrum fumigant, such as the date moth. The contribution of area-wide SIT to the management of populations that are pesticide resistant is an important “public good” that will be increasingly recognized in the future.

Historically SIT has been funded either all or in part from public investment. Various models exist for funding, including public-private partnerships. Some future programmes can be funded using farmer levies or area taxation, which has proven sustainable for the codling moth control programme in British Columbia, Canada. The 25 years experience of the sterile onion fly facility in the Netherlands — a totally private company supplying an annual control market — has focused on a single market and overcome earlier financial challenges. Cooperative area-wide ventures for SIT control of Medfly are beginning in citrus production areas in several countries around the Mediterranean, demonstrating the first private producer/private customer model for such a large scale. While operating costs can be raised, as for Medfly control in South Africa, the capital costs will be harder to fund, unless some of these private ventures get start-up support from public funds, such as is occurring in Brazil.

The increasing use of SIT for suppression, containment and prevention offers new opportunities for private investment since these could develop into long term supply and release programmes that would justify major capital investment in facilities, staff and technology. This new private capacity in sterile fruit fly production could also be harnessed for short-term eradication programmes provided large scale transport of the particular sterile insects is feasible from central production facilities.

There is yet little documentation of how to construct a sterile insect facility, but the lessons learned from fruit fly, Screwworm and Lepidoptera facilities have been freely shared, in particular through the efforts of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. Support in designing and equipping these facilities often is coordinated by the Joint FAO/IAEA Division, which requires the involvement of the national government in all assisted programmes. With the entry of the private sector into the sterile insect production and field release, there is an urgent need to clarify the protection of intellectual property that is developed under the United Nations system, specifically in IAEA, and to explore other barriers to collaboration with private entities.

As with all business ventures, a model that captures the probabilistic nature of costs and profits will give the best guide for decision making and periodic reviews. This is particularly the case with sterile insect production. Because the full capacity of a facility is not always met and field populations naturally rise and fall, these conditions can be taken into account in a probabilistic model. Assumptions also can be tested one by one to see the impact of such factors as the cost of the diet, labour rates, inflation, the cost of a loan and the time it takes to reach full production after construction. Pricing of sterile insects is another challenge, as there are few examples of commercial sales. Government financed facilities often do not accurately include capital costs even when sterile insects are sold. In the future more systematic collection of these figures will allow for better cost projections for new species and more accurate cost recovery.

There are considerable benefits to an international approach to the establishment of SIT facilities, through either private investment or through international donors. Tsetse production facilities, for example, could be built in several locations as “insurance” to the loss of single location colonies as SIT programmes get implemented. This approach to risk reduction may add to the overall cost but be essential for both commercial reliability and programme success, especially when large quantities of sterile insects are required. New international standards and consensus guidelines on the shipment and release of sterile insects may be a useful stimulus to further development of sourcing sterile insects from international production facilities.

In conclusion, there is growing evidence that application of SIT will increase and is attracting the attention of the private sector, despite individual programme funding limitations and research hurdles for some species. As private companies consider investment in large- scale sterile insect facilities, a range of considerations must be made. Many of the decisions about business structure, location (both general and specific), financing and insurance are similar to other businesses. However, the challenge of working with living organisms introduces other issues including the need to prevent the escape of any exotic or harmful species and the constant high quality standards that must be met.

Section 9 References and web sites

9.1 References

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9.2 Useful Web sites for updating research

International Atomic Energy Agency (IAEA)	www.iaea.org
International Database on Insect Disinfestation and Sterilization (IDIDAS)	www.infocris.iaea.org/ididas
African Union's InterAfrican Bureau for Animal Resources	www.au-ibar.org
Convention on Biological Diversity	www.biodiv.org
Department for International Development (DfID, UK)	www.dfid.gov.uk
Food and Agriculture Organization	www.fao.org
Insecta Ltd.	www.insecta.co.uk
International Finance Center (IFC) World Bank	www.ifc.org
International Plant Protection Convention	www.ippc.int
Investment Promotion Network (IPAnet)	www.ipanet.met
Islamic Development Bank (IDB)	www.idb.org
Office International des Epizooties	www.oie.int
Madeira Med	http://www.gov-madeira.pt/sra/dra/servapoi/madmed/MadMed.htm
Multilateral Investment Guarantee Agency	www.miga.org
Okanagan Kootenay Sterile Insect Release Programme, (OKSIR) Canada for codling moth	www.oksir.org
United Nations	www.un.org
United Nations Development Programme (UNDP)	www.undp.org
United States Agency for International Development	www.usaid.gov
USDA/APHIS	www.aphis.usda.gov
World Intellectual Property Organization (WIPO)	www.wipo.int
World Bank	www.worldbank.org
World Trade Organization	www.wto.org

Annexes

Annex 1

Case study of a Slovakian production facility: the application of the Model Business Plan from Project INT/5/145 to a specific facility

This case study was used to test the Model Business Plan. Conclusions from that test remain valid. Although the facility has not reached the production level originally anticipated and therefore none of the scenarios have come to pass, the actual figures for production capacity, costs etc., may easily be corrected in the model. The cost-of-labour assumptions are updated in Section A1.9.1.

On the supply side, the greatest impact is from a new sterile Medfly facility in Spain which has the capacity to produce up to 600 million sterile males per week. The potential near term demand far exceeds this level, however. Other changes in terms of prices of product, for example, can be assessed by changing the assumptions in the model.

For the time being, the InSecta-IZSAS Institute of Zoology, Slovak Academy of Science (SAS) facility has a production capacity of around 500,000 sterile Medfly males per week which have been used mainly for research purposes (e.g. EU 6th Framework Project, Cleanfruit). There are still plans to expand the operation. One option for the future is to build an egg producing facility to supply other sterile male-only Medfly facilities.

The tsetse facility is used as a back-up facility for African programmes such as the one in Ethiopia. Several thousands pupae per month are shipped from the facility already. The colony has 110,000 females of *G. fuscipes*, *G. morsitans morsitans* and *G. pallidipes*.

A1.1 Summary of the case study

This case study is a test application of the Model Business Plan developed under the International Atomic Energy Agency funding through the Technical Cooperation Department's Project INT/5/145. The results of the case study show that the specific case analysed, a proposed sterile insect production facility in the Republic of Slovakia, has considerable merit. A number of the issues raised in the Model Business Plan are covered by the Slovakia project's feasibility study and some issues are covered in much greater depth. The topics not discussed in the feasibility study (primarily intellectual property rights, development of standard operating procedures and an emergency preparedness plan and pricing of the product) may be covered in the next phase of that project's development and can draw on the Model Business Plan for guidance. The financial model from the Model Business Plan revealed the greatest difference in comparison with the static budgets presented in the feasibility study. Because the financial model allows for various assumptions to be tested, the basis for the original Slovakian assumptions was examined more carefully. Four scenarios are offered to show a range of outcomes depending on the various assumptions. While the Model does not represent reality, but rather a test of possible scenarios, the Slovakian proposal might benefit from considering the points raised using this comparison.

A1.2 Purpose of the case study

The Model Business Plan can be applied to a real case study for a proposed production facility in Slovakia. The proposal for this facility, which is the basis for this Annex, is laid out in detail in the document: *Novotny, J., Kozanek, M. and Beans, L.J. 2001. Feasibility study for sterile insect mass-rearing facility in the Republic of Slovakia. Vienna, Austria. Final Report of IAEA Project SLR5002. Forest Research Institute in Zvolen, Slovak Republic and IAEA, 104 pp.*

The primary purpose of this case study is to compare the points made in the Model Business Plan with a specific example. The Annex also provides an analysis of various financial scenarios for Slovakia using the model developed from historical data. The exercise may serve to improve the assumptions of the Slovakia project, but also to inform the creators of the financial model for future adjustments to its assumptions.

The proposed facility will produce sterile Mediterranean fruit fly (Medfly) and sterile tsetse for sale to projects in other countries. This case study focuses on the Medfly production portion of the Slovakia proposal, due to the lack of international data on tsetse fly production with which to compare that segment of the operation.

The final version of the feasibility study (Novotny *et al*., 2001) concludes that a pilot facility will be built for production of 65 million Medfly in collaboration with a private investment firm, InSecta Ltd. This project is proceeding in a time frame similar to that proposed for the full-scale facility. The full-scale facility has been postponed, but is still the ultimate intention of the Slovakia Team.

No details of the costs of this alternative pilot facility were provided in the feasibility study, other than round figures on the initial conversion/construction and equipping of the facility. Directors of the private investment firm involved chose not to share this proprietary information. For this reason, this case study covers only the full-scale production facility (and, as explained above, only the Medfly portion of that facility) and not the pilot plant. The same points and model could be applied to the pilot project by the management of that facility, just as they may be applied to other proposed and operating facilities in other countries.

The following outline follows the same outline and topics discussed in the Model Business Plan, albeit in far less detail. Reference is made to the relevant sections of the Model Business Plan to facilitate cross comparisons on each topic.

A1.3 Commercial issues for sterile insect production in Slovakia

A1.3.1 Role of private sector

The Slovakian proposal is for a commercially-operated business that will produce and ship sterile Mediterranean fruit fly (Medfly) for use in pest control programmes in various countries using the sterile insect technique (SIT) and tsetse fly for use in public and veterinary health programmes in Africa. The benefit to the Slovak Republic is the development of a biotechnology facility using technology with a long track record to produce a product with an established and unsatisfied demand. It was envisioned that the operation of this facility by the private sector would result in employment of both professionals and low-skill workers from

Slovakia. Training of employees and interaction with international experts is an integral part of the proposed business as well.

The proposal (Novotny *et al.,* 2001) was prepared through the Slovakian Government with the support of funding and technical advice from the International Atomic Energy Agency (IAEA). The original intention was to attract foreign investors using the feasibility study. Opportunities for Foreign Direct Investment (based on information from SARIO – Slovak Investment and Trade Development Agency) are discussed in the feasibility study along with details on the steps for setting up a business in the Slovak Republic.

Although direct investors were not identified during the initial phase of the preparation of the detailed proposal, a biotechnology investment firm did approach the Slovakian Government based on the work. At the time of this case study, a private firm established in the United Kingdom had begun raising the capital to proceed on a pilot version of this project.

A1.3.2 Organization of the production business

A1.3.2.1 Structure of the proposed business

The pilot project will be a joint venture, with the Government of Slovakia holding a portion of the shares (Novotny, pers. comm., 2001) and the private investor holding presumably the majority of shares. This information has not been confirmed in the feasibility study or by the private firm.

The participation of the government will allow for continuing interaction with IAEA technical staff, which is a critical point for the success of the operation as long as other mechanisms for technology transfer to commercial entities have not been developed within IAEA. For this reason, some participation of the Government is expected in the full-scale facility as well. This is discussed in the Model Business Plan, Section 3.2.

A1.3.2.2 Financing

The feasibility study describes financing of the full-scale facility by means of a loan for US$15 million to cover site development, design, construction, and equipping costs. US$13.52 of this is attributed to the Medfly production.

The Government of Slovakia is expected to provide in-kind contributions, such as land, for financing its portion of ownership rather than any cash contribution for this project. It may also provide tax holidays, investment incentives, employment promotions or other forms of support. These incentives, which are available to any qualifying business, will not be the basis for any government ownership in this project.

Private investment may be in the form of cash or guarantees of a loan for the construction and operation of the production facility. The advantages of using a loan over cash are outlined in the Model Business Plan, Section 6. The repayment of a loan will reduce the immediate profit of the facility, but may allow investors to maintain their assets as income generating by providing them as collateral for a loan rather than giving the full cash required in the first year.

The European Investment Bank (EIB) provides a range of financing instruments to meet the needs of small and medium enterprises in EU countries, including Slovakia since its accession. With that purpose, the EIB provides credit lines (EIB Global Loans) to local banks in Slovakia (reference 15). The Ceskoslovenská Obchodní Banka, for instance is one of these intermediary banks. The EIB finances projects with total cost between €40 000 and €25 million. The National Agency for the Development of Small and Medium-Sized Enterprises is administering several similar support programmes (reference 16). Other indicators confirm that capital is available for Slovakian business start up.

According to the Economic and Financial Data for the Slovak Republic, in October 2001 the commercial bank average lending rate was 9.91 percent. This was down from 10.15 percent in the previous month. The figures correspond to the data described on the International Monetary Fund's Dissemination Standards Bulletin Board (DSBB) and so could be described as accurate (reference 3). The feasibility study proposes an interest rate of 8 percent. This may be possible since the investment is arising at least in part from outside of the country and rates in other parts of Europe are much lower.

A1.3.2.3 Competencies identified for this business

The organizational structure (Novotny *et al.*, 2001, Chapter IV p. 39) has the Board of Directors interacting with the Director of the production facility, who in turn is in charge of sectors consisting of:

- production;
- research and development (including quality control and technical support to clients);
- engineering (maintenance and environmental);
- business management (including finance, accounting, payroll, inventory, sales and marketing, shipping and logistics).

There is also a Corporate Management sector that works with the Director. This division includes competencies in auditing, legal issues (patents, etc.), computer support, human resources (personnel, training, labour-management relations) and public relations, including the relations with the Government. Some of these competencies may be obtained by outsourcing, for example with auditors or legal counsel. Cleaning services and security will be contracted according to the feasibility study.

This range of competencies corresponds to those of facilities operating in other locations and covers the areas highlighted by the Model Business Plan.

A1.3.3 The production site

A1.3.3.1 Country selection

Slovakia has many advantages as a site for this production facility. Some of those discussed in the study are:

- location;
- availability of resources;
- labour force;

- low costs;
- accessibility;
- political stability;
- quarantine security;
- close to IAEA laboratories in Seibersdorf;
- project compatibility with the Slovak Integrated Plant Protection Policy and the "National Programme for Development and Use of Bio-technologies in Slovakia" (Novotny *et al*., 2001, Chapter I).

The attached information on taxes and duties, compiled independently of the feasibility study, provides additional motivation for choosing Slovakia as the site for this facility (Section A1.9.1).

A1.3.3.2 Specific site selection

The selection of a specific site in Slovakia was carried out using a weighed ranking system (Novotny *et al*., 2001, Chapter IV). The ranking system included the fundamental criteria proposed in the Model Business Plan and listed again in Annex 11 of that report.

A1.3.3.3 Appraisal value

Section 3.3 of the Model Business Plan presents appraisal as one of the factors to consider when choosing a production site. The unique nature of the sterile insect production business makes potential subsequent uses of the building a consideration for investors or sources of loans.

A reasonable rate of depreciation was contemplated in the feasibility study's financial analyses. The rate was (Chapter IV, Novotny *et al*., 2001) 10 years for the cobalt source, 15 years for the production equipment, 4 years for the furniture and office equipment and 40 years for the buildings, roads and utilities added for this project. For ease of use, the Model Business Plan adopted a merged rate of 10 years for depreciation on all assets, but depreciation by category is more precise and may be maintained by the Slovakia project.

For historical and cultural reasons, an appraisal should distinguish Market Value from values determined under communist social systems. Market Value does not use pre-determined coefficients or ratios given by a government agency, although it may extract such coefficients from a study of market sales data. Market Value does not rely on "amortization" or "amortizatzia" as used under many socialist regimes. Instead, it uses "depreciation" but only as measured by actual market reactions to conditions in the property or around it (Kaufman, 2001).

A1.3.4 Protection of intellectual property

The Slovakian proposal does not discuss the development of intellectual property or plans for its protection in the future. On the other hand, the private company collaborating on the pilot facility has a parent company, InSecta Ltd, which is based largely on technology development and its commercialization. This by nature will require protection of all intellectual property developed through that company in order to generate capital and secure the future of the business.

Clearly, new issues for the protection of intellectual property may arise with the involvement of a private company in what has historically been a government industry. These issues are outlined in the Model Business Plan, Section 3.4. The Slovakian Team, which includes Government officials, is benefiting from a wide range of technical assistance from the IAEA, through both project funding and informal consultations with technical staff. Eventually even the biological material to start the production colony and filter colony will all come from the Joint FAO/IAEA Division.

When assistance is through a contract with IAEA, the intellectual property rights pass to the IAEA per the terms of the contract. However, the IAEA currently does nothing to protect this intellectual property. A private business may feel compelled to take out patents on innovations that might otherwise be attributed at least in part to the IAEA, in order to protect their own financial investment in research and technology innovation. Any innovation presented in the public domain can no longer be patented. Such issues should be discussed between the private company and the IAEA in detail prior to additional assistance. Understandings (either by mutual consent or in writing) on intellectual property protection may need to be updated as the IAEA policy evolves on the matter.

For the time being, the key element of the IAEA (this covers FAO/IAEA as well) contracts regarding this issue should be:

- To prevent a private firm from usurping intellectual property by obtaining patents on something developed by the IAEA.
- To allow the IAEA and its cooperating member states to utilize and benefit from innovations developed primarily due to IAEA assistance or foundation research.
- To prevent the misuse of any IAEA innovation either by the receiving party’s negligence or by the innovation being passed on to another party without the proper oversight and knowledge of the IAEA.

These elements will also serve to protect the reputation of the sterile insect rearing process and SIT in general. In addition, clarification of the nature of the innovation and its proper application can reduce potential liability for IAEA or the private company.

If a private company wishes to clarify the relationship before IAEA reaches conclusions internally on protection of intellectual property, then its managers may wish to follow the approaches of United Nations agencies that are further along in the cooperative programmes with private sector, particularly the World Health Organization (WHO). The private sector may take the lead in proposing contractual language to the Agency.

The Food and Agriculture Organization (FAO) has altered its internal system to allow for the creation of revolving accounts that receive royalties on FAO-supported inventions or innovations. These funds may be used by the same programmes to support on-going work. Until IAEA better protects its intellectual property, private companies will not be expected or even allowed to pay royalties or other forms of financial support for use of IAEA developments.

On issues of intellectual property protection outside of the United Nations system, Slovakia will eventually align with the intellectual property laws of the European Union (EU). The EU Ministers have attempted to create a Community-wide patent providing a “one-stop” application process, but negotiations on this have faltered. Country objections appear to be primarily around a perception that the procedure will discriminate against some of the EU’s 11 official languages, with English being chosen by most applicants. The current proposal would allow an applicant to choose whether the patent claims will be issued in English, French or German plus the applicant’s mother tongue, with only a summary in all 11 official languages. The proposal would reduce costs for translation of new patents down from approximately €11 500 to less than €3000 (Mann, 2001). It does not appear that this will be resolved in the near future.

As a member of the World Trade Organization (WTO), the country must comply with the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). The implications of this are covered in the Model Business Plan, Section 3.4.

A1.3.5 Insurance requirements and liability

The Slovakia proposal includes insurance as a line item in the budget, without providing details on the nature of the insurance that will be purchased. A list of the types of insurance needed by a production facility (e.g. fire, theft, and vehicle) appears in Section 3.5 of the Model Business Plan. The fact that the company will include government ownership may complicate the liability and should be pointed out to the insurance agent at the time of purchase of a policy. Local government policies will influence the approach to insurance for employees and management, such as health and life insurance.

Contractual language should cover the fundamental liability issues regarding the “performance” of the sterile insects once released. The Slovakian Team should analyse the need for insurance on individual shipments of insects or a blanket policy that would cover losses during that phase of the business.

While political risk insurance may help in the case of a client defaulting on their agreement to buy, the Slovakian Team may wish to strategize on ways to lower risks for which insurance does not exist. Risks such as the loss of a colony or other reasons for sudden drop in production and the inability to supply a contract should be reduced to the degree possible through a variety of means. This concept is introduced in Section 3.5.5 of the Model Business Plan.

A1.3.6 Market considerations about technologies

Slovakia has experience with the use of biological control agents and mass release of insects for this purpose. In some forest situations, alternatives to chemical controls have been used for the past decade. Mass trapping programmes, for example of bark beetles in spruce, have made the general public aware of the use of pheromones (Novotny, pers. comm., 2002). In this sense, Slovakia is well prepared for a biological production facility.

The country is also familiar with nuclear technology. There are two nuclear power stations, one of which was constructed in the past three years. This use of nuclear technology allows Slovakia to be a net exporter of electricity. Nuclear technology in medicine is also well established, both for research and applied uses.

The Slovakian feasibility study discusses the use of genetic sexing strains of Medfly and explains the purpose of this genetic engineering. Meetings in January 2002 with the Ministry of Agriculture's plant protection agency indicated an acceptance of the technology and some agreement on what may be used for biosecurity measures.

The majority of people interviewed for the Slovakia study appear to understand the technology and be supportive of the project.

A1.3.7 Other commercial considerations for marketing sterile insects - public relations and community support

The Slovakia team has taken community support very seriously and ranked it as an important criterion when choosing the final site for a facility. Some public education programme may need to take place before the construction of the plant. The Slovakia Team intend to give regular updates to the local government through the life of the project.

A1.4 Markets

Two species will be produced in the full-scale project: Medfly and tsetse fly. The pilot project will focus on one species – Medfly. Markets for sterile moths were considered, but the feasibility study is limited to detail on the two selected species.

A1.4.1 The market for sterile Medfly species

The feasibility study identified market demands for sterile male Medfly based on the cited studies in the table below. It also identified the Maghreb market, described in another IAEA study, Portugal outside of Madeira, Spain (Valencia), Sicily, South Africa and South American markets.

Table A1.1. Sterile Medfly males needed for 8-year projection (based on IAEA projects)

	Millions of sterile male Medflies required per week							
Project name	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
A. Cyprusmed	0	160	160	0	0	0	0	0
B. Eastmed	5	332	663	713	1,044	1,450	1,007	220
C. Egyptmed	0	249	480	1063	831	0	0	0
Total	5	741	1,303	1,776	1,875	1,450	1,007	220

Source: Novotny *et al.*, 2001.

The IAEA projects referenced in the Table above include the following countries:

A. Cyprus
B. El Arsh (Egypt), Gaza, Israel, Jordan, Lebanon, Syria, Turkey, and Palestinian Authority Territories
C. Egypt

Changes in the markets, some temporary and some indefinite, have caused the more recent market report in the Model Business Plan (Section 4 in the report, and the Table below) to revise down some of those figures.

For example, many people feel that Egypt is unlikely to start an SIT programme against Medfly in Egypt without measures to control the peach fruit fly (*Bactrocera zonata*), which is established and wide spread there and is of greater quarantine concern for the region. The Maghreb eradication market has not taken off as originally estimated and will probably be replaced by some suppression or local eradication programmes in Morocco and Tunisia at the most. Outside of Israel, the Eastmed project may face delays due to the political situation, as will Cyprusmed. At the same time, smaller efforts such as that proposed by Malta, may come sooner than those estimated just two to five years ago.

Table A1.2. Sterile Medfly males needed for 8 year projection that are not linked to a supply

Project name	Millions of sterile male Medflies required per week[a]							
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Portugal-the Algarve[b]	65	117	117	117	177	117	117	117
Other areas Portugal	206	206	206	206	206	206	206	206
Spain[c]	200	200	200	200	200	200	200	200
Jordan/Israel[d]	100	100	100	100	100	100	100	100
Morocco[e]	32	32	542	542	542	542	542	542
Sicily[f]	185	185	185	185	185	185	185	185
Corsica, Sardinia[g]	30	30	30	30	30	30	30	30
Western Australia[h]			26	55	102	98	8	7
Total	818	870	1406	1435	1542	1478	1388	1387

[a] Some programmes will not run 52 weeks a year because of the seasonality of the populations (e.g. see footnotes 7 and 8).
[b] The assumptions and analyses for Portugal suggest the most likely uptake as indicated (Mumford & Larcher-Carvalho, Annex 2 of this project report).
[c] Although studies exist regarding the actual demand in Valencia, they were not available to the authors. This is simply a best guess at this time.
[d] Novotny *et al*., 2001 and import statistics from the Guatemalan facility. This is for the reduced programme. If the Eastmed programme were implemented as originally planned, demand would be closer to that shown in the Table A1.1.
[e] Because of the importance of the pilot project to convince growers of the results, the smaller area is shown here to repeat two years before a full national programme. If a national programme were adopted, a phase in period is expected with the peak years appearing in the last two columns. Figures would be similar for suppression or eradication (Ait El Mekki, Mumford and Quinlan, Annex 3 of this report).
[f] Novotny *et al*., 2001. Choosing a number that represents the estimate for Sicily alone.
[g] For Corsica, releases will be over a 16-week period each year. Extrapolating the number of sterile flies needed given the area in citrus and other fruit. This would be for a suppression programme. Eradication would require much greater numbers since there are areas with garden hosts and wild hosts including *Opuntia* and black nightshade all over Corsica. Based on the report “The technique SIT in Corsica”, which is part of FAO/IAEA 2000a.
[h] It is assumed that an eradication effort would be a phased programme over six years with a maximum control area of around 1,000 km^2 per year in the peak year. This would require release of about 100 million sterile male flies per week for 40 weeks at the peak time. The Perth facility has a capacity too low to supply the peak years, although it might supply the start up and final years (Mumford *et al*., 2001).

The current demand for sterile Medfly around the world is estimated in Section 4 of the Model Business Plan, but must be updated with new developments. Of those listed, several programmes are linked to production facilities that are either in the same location or are sponsored by the government of that area. They are mentioned since the demand continues, even if the linked production facility has a temporary loss of production or temporary excess.

The more immediate demand that does not appear to be met is presented in Table A1.2. Of this list, only the programme in Israel is presently releasing sterile Medfly, although both Portugal and Australia have programmes going on in other parts of the country. Such a table is not representing the true market because the first year of one project may not correspond to Year 1 of another project. Even if each of these proposed programmes proceeds, this information will be very dynamic and such a table can only indicate a trend.

In terms of supply, Tunisia has constructed small production and release facilities for Medfly and, if a larger facility were built (currently on hold), would have some advantage in the French-speaking and Islamic markets (e.g. Morocco) over Slovakia.

These revisions to the Slovakian projection support the expert opinion summarized in the Model Business Plan: that the market for sterile Medfly could far exceed the level of production proposed for the Slovakia facility, at full-scale 1000 million per week (see comments in Section 7 regarding capacity versus actual production). In other studies, the upper limit for demand in the Mediterranean Basin was estimated as 50-75 billion (FAO/IAEA 2000a). It should be kept in mind, however, that rather than reliable figures, these comments show that the market situation is dynamic and must be reviewed continually.

One should also consider the percentage of male Medfly produced in comparison with those reared up and released. At each step from capacity of the facility through to release there will be some loss, so that 1000 million capacity may result in closer to 800 million released. It is significant that the demand shown in Table A1.2 is primarily for suppression rather than eradication programmes and therefore will be continual over the years, although not over the course of each year (52 weeks per year). In summary, seasonal fluctuations may prove a greater challenge to the Slovakia facility than finding sufficient demand on an annual basis.

A1.4.2 The market for sterile tsetse fly

The feasibility study focuses on the humanitarian market for tsetse fly. Other markets able to afford direct purchase, including Botswana, may be considered when the full-scale project begins. Critical to any analysis of the tsetse market is the decision about which species will be reared at the Slovakia site. The strategy to wait for commitments from international entities (UN, donors, foundations, etc.) before committing to this aspect of the project is a good one. The market for tsetse and factors impacting the implementation of SIT for that pest are discussed in the Model Business Plan, Section 4.5.

A1.5 The production process

A1.5.1 Physical plant

A production facility design is shown in plan form (Figure V/3, page 29 *in* Novotny *et al.*, 2001) with all the necessary components for production of two species with different needs. Separate modules for various stages of Medfly production and for tsetse production were shown in this design. Specifications on the design of the pilot facility are not presented, but the production level is sufficiently low to make a modular approach inappropriate. Handling will be primarily hand labour rather than automated in the pilot facility. Advances in automation of tsetse rearing should be included in the full-scale facility.

A1.5.2 Operation of the facility

The Slovakian proposal has a description and schematic of the production process for both Medfly and tsetse (Chapter V, Figures V/1 and V/2 *in* Novotny *et al*., 2001). The detailed explanation of steps in the production and maintenance of the breeding and filter colonies are excellent introductions to the operational steps required.

A1.5.3 Addressing possible hazards

A1.5.3.1 Best practices and SOPs in production

Each production facility must prepare standard operating procedures (SOP) covering production and sterilization, as well as addressing shipping of the product and other points at which hazards may arise. The Slovakia Team is well placed to interact with IAEA as new international standard operating procedures are developed. Indeed, members of the private firm have already participated in several IAEA meetings as experts in their fields.

It is recommended that the first year of construction, before operations begin, the management team is fully employed to develop SOPs, begin marketing efforts, prepare details on the work plan and organize hiring of personnel. If the same group as the pilot project develops the full-scale operation, their existing staff may cover this. Even for the pilot project, at least a partial staff or contracted management is needed some months before operations begin, to ensure the successful launch of a new business.

A1.5.3.2 Special hazards for mass rearing tsetse fly

The feasibility study indicates that the only special handling of the bovine blood to be collected and used for the diet for tsetse fly is irradiation. This treatment will kill a number of possible pathogens that could contaminate the supply. The bioassay will detect other contaminants, such as unrecorded use of bovine drugs that will adversely impact a tsetse colony.

There is no mention in the feasibility study of special practices to prevent the possible introduction of bovine spongiform encephalopathy (BSE). Although there is no evidence that blood-feeding insects could transmit BSE, experts have not yet eliminated the possibility. It is known that prions are not controlled by irradiation in the way that other pathogens are (see also Section 5.3.2 of the Model Business Plan report).

A1.5.3.3 Biosecurity at production site

Biosecurity measures are not outlined in the study. However, the design for the full-scale facility does show special entrances that will prevent escapes. The management team will need to consider whether other measures should be taken, given the relatively low risk of survival of Medfly and the impossibility of tsetse fly survival for biological reasons. A system of traps for Medfly should be instituted to monitor for any escapes or introductions from other pathways. This decision should be made in conjunction with the relevant government authorities in charge of plant health, beginning with the pilot project, and for animal and human health when tsetse production is initiated. These authorities, on their part, should respect the international opinion that these risks are low. This calls for only measures that are in proportion to those very low risks.

A1.5.3.4 Emergency preparedness plans and security

The management team will need to develop an Emergency Preparedness Plan for the construction phase and then for the operation phase. This is not necessary for the feasibility phase. Elements generally included in an Emergency Preparedness Plan are discussed in the Model Business Plan, Section 5.3.4 and in Annex 8.

A1.5.4 Logistics and transport issues

A1.5.4.1 Current practices in transport and handling

The Slovakian study does not enter into detail on the handling for transport of the sterile insects. It is anticipated, however, that existing practices will be followed regarding packaging, shipping and labelling.

The site for the pilot facility (Zvolen, Central Slovakia) is much further from international transport links, particularly the international airport facilities in Vienna, than the original full-scale proposal. Since the split of Czechoslovakia in 1993, the Slovakian Government has given high priority to its transport policies. The goals set in place are to build an extra 460 km of highways before 2005. However it must be noted that until 1996 highways represented only 1 percent of the road system (198 km) (reference 1). This increased distance may affect the requirements for ground transport to the airport, in terms of temperature control and total time of transport.

Although the airports at Bratislava, Košice, Zilina and Sliac are being modernized (reference 1), it is still anticipated that shipments will be routed through Vienna's airport. There is no discussion in the feasibility study of the impact of the change of location. This may require further research, including a costing of transport costs from Zvolen to compare with the chart prepared comparing Bratislava with Guatemala air cargo rates (Chapter VI *in* Novotny *et al.*, 2001).

A1.5.4.2 Risk management in transport

The Joint FAO/IAEA Division has recently developed a guideline for packing, shipping, holding and release of sterile flies in area-wide SIT programmes. The guideline includes measures that will reduce the risk during shipping and transit to a negligible level. If the operators of the facility follow these guidelines, no other measures are needed. It is recommended that the facility operators and all other operators involved in the process proceed with this approach whether obligatory in their country, or not, to avoid problems in transport.

A1.5.5 Environmental issues

A1.5.5.1 Environmental regulations at production site

Slovakia has strict laws to protect the environment, in particular the Environmental Protection Act. The law states that anyone who causes environmental damage is liable for all the clean up costs. Furthermore, it states that anyone who discovers environmental damage must take steps to minimize it and to notify the authorities. At present, most foreign investors essentially ignore environmental policy, calculating the risk for liability as low as they do not believe that action will be taken against them. However this is likely to change in the future with accession to the EU. It is possible that the government will create incentives for self-assessed environmental good practice, similar to schemes carried out in the EU (reference 13).

Environmental indicators for agriculture that include issues such as biodiversity, wildlife habitats, socio-culture and greenhouse gases have been developed under coordination of the Organisation for Economic Co-operation and Development (OECD, 1999). Using these terms and concepts will help to communicate environmental studies to the rest of Europe.

A1.5.5.2 Environmental impact assessment of SIT programmes

A full Environmental Impact Assessment (EIA) is not provided in the proposal. Conversations with the Ministry of Agriculture (January 2002) indicate that an EIA will not be required for the renovation of the existing building for use as the pilot facility. For the full-scale facility, the following points are presented, satisfying the basic requirement for consideration of environmental impact (Chapter VIII *in* Novotny *et al*., 2001):

- Safety and health in the production environment: the technologies used for rearing are simple and not hazardous, no toxic compounds are used.
- Radiation risk assessment: the irradiators are sealed systems, protecting operators or local residents from any health risk.
- Waste management and recycling: waste by-products present no environmental risk and are mostly degradable. The facility does not produce any toxic waste. Predicted levels of water, electricity and gas consumption are estimated in daily, weekly and yearly increments. Waste water is treated before being released into the public sewer system.
- Environmental impact of target insects: the geographical range and prevalence of the target insects, such as Medfly and tsetse fly, and the benefits of control via SIT.
- Pest risk assessment for reared insects: the species to be reared in the facility are out of their global range and unable to produce self-sustaining populations in Slovakia.
- Environmental impact assessment of the production facility: governmental analysis of the production facility and its classification.

All of the points above are discussed in Section 5.5 of the Model Business Plan, along with the World Bank criteria for an EIA. The pest risk assessment may need to be modified to integrate any measures taken due to the fact that Medfly is listed as a quarantine pest in Slovakia. When Slovakia accedes to the European Union, it is likely that this species will be removed from their quarantine list (according to meetings January 2002).

A1.5.6 Other regulatory concerns

A1.5.6.1 International conventions, protocols and guidelines related to sterile insects

The Model Business Plan, Section 5.6, describes the role of various international conventions and protocols in relation to sterile insect production, transport or release.

The Republic of Slovakia is a contracting party to the World Trade Organization and the Convention on Biological Diversity (CBD). In 2003, the Slovakian government ratified the Cartagena Protocol on Biosafety, which requires certain precautions regarding transport of living modified organisms that are potential pests. Slovakia is a member of the World Organisation for Animal Health (OIE), and became a contracting party to the International Plant Protection Convention (IPPC) in 2006. The country is also active in the European and Mediterranean Plant Protection Organization (EPPO).

A1.5.6.2 Regional and national laws regarding release

The feasibility study fully discussed relevant EU directives about plant and animal protection. This site will not be using genetically modified insects, in the sense of the legal definitions, so there is no need to raise this issue with regulators.

The Model Business Plan was written subsequent to the Slovakian proposal and outlines a more recent EU Directive related to this issue. It also highlights results of a study by Fisahn (2001) considering the same laws discussed in the Slovakian study in Section 5.6.

A1.6 Financial information for a production facility

A1.6.1 Construction of a production facility

The Slovakian full-scale facility will cost an estimated US$15 million for design, construction and equipping. US$13.52 million is for the production of Medfly. This section seeks to compare that to costs from other facilities already operating or proposed in other parts of the world. There are few international data for tsetse production facilities assembled to allow for comparison of costs. The facilities producing Medfly are noted in Section 6 of the Model Business Plan. Those Medfly facilities with known approximate costs of construction appear in the table below. In this case, the pilot and full-scale facilities proposed for Slovakia are also added to the comparison.

Table A1.3. Recent construction and planned expansion of Medfly facilities with estimated costs and production capacities (output of male Medfly)

Site	Construction From	Production capacity millions/week	Approximate cost US$ million (cumulative for sites in stages)
Argentina	1991	200	4.5
Chile	1992	50	2.3
El Pino stage 1	1996	500	4.2
Madeira	1996	50	2.6
W Australia pilot	1997	20	0.5
S Africa stage 1	1998	8	0.3
El Pino stage 1+2	1999	800	6.3
El Pino stage 1+2+3	2001	1600	15.7
S Africa stage 1+2 projected	2003?	200	1.8
S Africa stage 1+2+3 projected	2005?	400	3.1

Taking these same data, the full-scale facility in Slovakia (top square in Figure A1.1) appears to be more expensive to construct than the international average. There may be good reasons for this, but the investors may wish to have those reasons clearly enumerated to consider in the context of the choice of location.

The pilot facility (lower square), on the other hand, falls below the line of international costs. This is not surprising since the cost of land, infrastructure such as roads and possibly effluent treatment do not appear in the costing of US$679 000 and are presumably the in-kind contribution of the Government of Slovakia. There is also more variation at the low end of the production capacity, although still resulting in a linear regression.

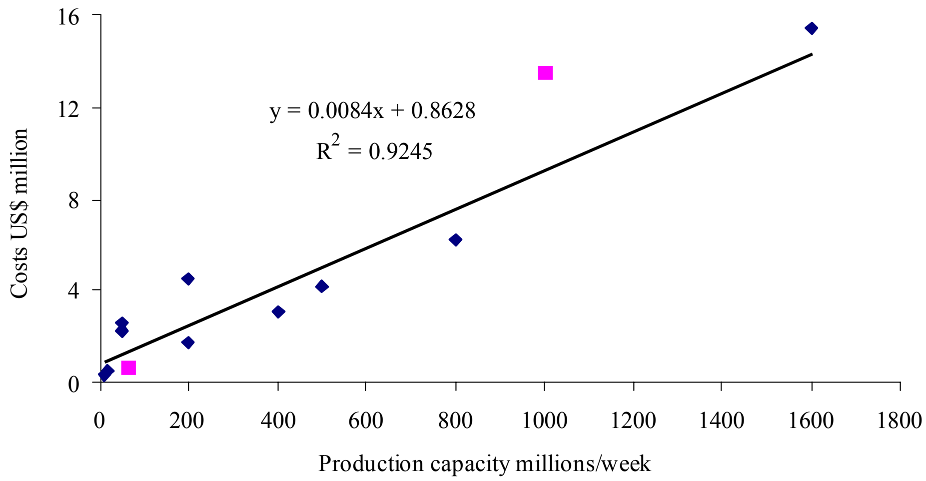

FIG. A1.1. The capital costs of a range of Medfly SIT factories including two facilities in Slovakia.

A1.6.2 Operation of a production facility

The feasibility study showed budgets based on fixed values estimated from information current at the time of that study. Under the Model Business Plan a dynamic financial model was developed that allows one to test various scenarios using different values for costs, capital outlay, interest rate or other factors. Probabilistic analysis applied to the values then allows the investor to see the likelihood of achieving profit goals over a given time period. The model was developed for a ten year time period.

In applying the financial model, the line items from the Slovakian budgets must be matched up or reallocated. There is usually no reason for one approach over the other; these conversions are made only to fit into the existing format of the model. The breakdown of figures is thus explained in Table A1.4.

A1.6.3 Pricing of the product

The feasibility study sets the price for one million Medfly at US$350. This is within the competitive range of pre-transport prices set by other facilities (primarily the one in Guatemala). Although it is not explicitly said, it appears that this value is chosen because it is the price charged by the Guatemalan facility. In fact, the financials for the full-scale facility indicate that the actual costs will be much less. (This assertion is disputed by approaching the pricing with slightly different data in Scenario 3.)

Table A1.4. Slovakian Operating Budget for Medfly converted to the line items used in the financial model from the Model Business Plan

Operating budget (Novotny *et al*., 2001, Table VI/6, p. 59)	**In the financial model appears as (or comments on):**
1. Number of staff years	Figures used are from study, except that the administration is put into Scenario 2 a year earlier.
2. Salaries and benefits	In the model, labour is presented as both fixed (administration) and variable (production related work force). The line item from the Slovakian study is broken down in Table VI/2 "Estimated Staff Requirements for at Full Production", but not distinguished on an annual basis nor broken down in the Operating Budget. The breakdown used is taken from that staffing table using their assumption in Scenario 1 that staffing reaches the full level in Year 2 even though production is not at full level until Year 4. Other Scenarios increase the variable labour stepwise in line with the increased production. See also comment 16. The now two line items resulting are both subjected to inflation in Scenarios 2-4.
3. Training and related travel	In the model this is contemplated under the quality management line.
4. Transportation (domestic)	This line is combined with the leasing of vehicles (below) and inserted in the model under transportation.
5. General and administrative supplies	Costs of supplies not associated with production are added to utilities and communications as a composite figure.
6. Medfly diet	The diet is the most sensitive item in the financial analysis. It is equivalent to the same line in the model. The figures in the study were not independently confirmed.
7. Other production/lab supplies	Added to the quality management line (see comment 3), which was not distinguished in that way in the study.
8. Production and shipping supplies; maintenance supplies and parts	The total of these two lines is equivalent to General Supplies under variable costs in the model.
9. Utilities (electricity, water, natural gas), telephone service, and internet	These five lines, (plus admin supplies comment 5, computer leasing and printing comment 14) are combined to equal utilities and communications in the model.
10. Waste disposal and waste water	These two lines are combined to put in the place of effluent management.
11. Depreciation (cobalt source, production equipment, furniture and office, buildings, roads, utilities)	This subtotal is used as if it were a combined linear 10-year depreciation, as shown in the model.
12. Equipment leasing	This cost is added to the general supplies, since the value of the figure suggests minor equipment that would normally be purchased in other operations.
13. Facilities repair and remodelling	This is considered as part of depreciation in the model and not a separate line item, so that this figure is essentially lost.
14. Computer leasing and support; printing and binding.	These two figures are added to utilities and communications, as a part of that aspect of business.
15. Security	Is combined with insurance (comment 19) to correspond to Insurance/security (loss and liability) in the model.
16. Cleaning service; building and grounds maintenance	Added to the administration cost since it is shown as a fixed cost labour.
17. Equipment maintenance	This line item is shown as a fixed cost and is added to Quality management.

18. Vehicle leasing	Part of transportation. See comment 4.
19. Insurance, buildings and equipment	Added to security (see comment 14). The model includes other types of insurance such as liability and "keyman".
20. Research and consulting services	This value in the Slovakian budget seems too low to represent actual research, so it was allocated to the Quality line item in the model. There is general agreement that much more R&D is required so in the model there is a separate line for R&D of $250 000 per year. Any input from IAEA or donors should be considered in this line in the future. For now based on our interpretation of the budget, Slovakia shows having nothing in that line in Scenario 1 and the figure from the model is used in Scenario 3 and 4.
21. Marketing and public relations	Sales/promotion in the model.
22. Overhead	All the costs normally associated with this term (administration, telephone, office, etc.) are already detailed. A contingency figure is not required with the addition of the probabilistic analysis.
23. Interest on 90% of the loan	The loan repayment and interest is recalculated based on the $13.5 million portion of the Medfly facility and the interest rate of 8%, reported in the study. Although the study shows the payment of interest on the capital outlay in Table VI/6 of the Model Business Plan, it reports the payment of the principal (which presumably comes from the profit line) in a separate table. These are both shown in the same spreadsheet in the model. The model has set the repayment period for the capital outlay loan as five years. (The line of credit is paid as soon as possible – see comment 28.)
24. Unit cost of production	This has been recalculated. See the discussion on pricing in the report (Model Business Plan, Section 6.2). The difference between calculating the unit cost weekly and quarterly can be significant since real costs are not captured in the shorter time frame.
25. Unit sales price	The maximum competitive sales price is set in the model as $375 per million. Clearly a lower price ($350) will be competitive.
26. Gross income from sales	The study shows the sale of 250 million Medfly the first year, 500 the second, 750 the third and then the full capacity of the plant – 1000 million from the fifth year on. In the scenarios presented, sales remain the same while the capacity changes to allow for some maintenance rather than assuming continuous 100% production.
27. Gross profit margin	In the model, there is a mechanism for establishing the expected profit on sales in order to set the price. The price is set as the cost plus this management-determined variable of profit. In the example presented in Section 7 of the Model Business Plan, a figure of 10% is chosen but other values could be chosen. The upper limit of the profit margin is determined by the maximum price per million flies that is competitive.
28. Pre-tax profit (10 year tax holiday)	The model does not include taxes so this is equivalent to the cumulative income minus costs.
29. Missing from the Table VI/6	A **line of credit** to cover cash flow needs in the start up years is not contemplated in the study because the study shows no losses beginning in year one. In the model, year 1 begins with the construction phase. Also values differ, so the line of credit is added to the degree that it is needed (just as in the original model). The **cost of opportunity** (what the money could have been used for if not invested in this facility) is not included in the study. Cost of opportunity is shown as similar to (but not greater than) the interest rate on the capital outlay loan. Otherwise, investors would choose the other opportunity. **Labour inflation rate** in the model is set as 6% beyond the inflation that impacts all the costs and prices. Scenario 1 has no inflation, reflecting the assumption in the Slovakian budgets. In Scenario 2 a high inflation rate is used in order for the minimum wage in Slovakia to reach the 2001 level of Portuguese wages within ten years. For assumptions behind this inflation, see Section A1.9.2.

The price for the pilot project Medfly is not mentioned, but is assumed to be the same US$350 per million. Pricing for tsetse fly will be a more difficult figure to calculate given the paucity of data and lack of international trade in this species.

In the scenarios presented, the competitive price is raised to US$375 since the Guatemala facility raised its prices to that level subsequent to the Slovakian proposal. The price may continue to rise, especially after the Guatemalan facility stops selling its excess outside of the region. It is an appropriate price to use for the current analysis.

The Slovakia Team may wish to develop a pricing policy based on some other approach than competing with the one facility that dominates the world production. Alternatives to pricing are proposed in the Model Business Plan (Section 6). These alternatives become more viable as the Guatemala facility withdraws from international trade to focus on the immediate interests of the Governments that paid for its construction.

A1.7 Synthesis of business information

Required infrastructure investment, operating budgets, cash flow analysis, break-even analysis, shipping costs for pupae and other financial analyses are all examined by Novotny *et al.*, 2001, Chapter IV. The financial model developed under the Model Business Plan uses different assumptions and, to the degree possible, international data. The differences do not imply that the Slovakia study is wrong, but rather that with these other assumptions and approaches to business, other figures will result. The model is for a generic facility, shown with the theoretical capacity to produce 1100 million Medfly per week (this factor can be manipulated within the model). This generates a potential sales volume of 972 million/week assuming a designed overcapacity of one eighth to allow for scheduled maintenance and unforeseen production shortfalls. The model provides a framework to compare business plans based on different assumptions on input costs. The limitations of the model are discussed in Section 7 of the Model Business Plan report.

Several scenarios are presented in this section. Each one is begun in 2004, which was agreed in January 2002 meetings as more likely than 2002 for the full-scale facility.

- Scenario 1 attempts to put the values from the Slovakia Medfly Operating Budget into the general model. Because of some differences in the basis of the line items some values from the Operating Budget have been reapportioned to different headings (explained in Table A1.4 above), but the overall values are kept. This shows their assumptions using the generic model.

The other scenarios apply some modified assumptions, thus allowing a comparison of outcomes based on estimates of international values.

- Scenario 2 copies the assumptions of Scenario 1 except for the labour line items. A labour cost inflator is added to estimate the effects of wage harmonisation and inflation across the EU in the next years and the variable labour is shown in relation to the production, to facilitate the application of the inflation equation.

- Scenario 3 applies several assumptions from the generic model (no sales in year 1, higher capacity to give a production buffer, higher interest rates, higher R&D and quality management budgets, higher diet costs, and, as before, an adjustment for increasing labour costs as Slovakia moves to EU levels).

- Scenario 4 the same as Scenario 3 but assumes a lower capital cost for the factory based on a regression calculation on other international factory costs (Figure A1.1).

These scenarios are discussed in more detail, with comments on the assumptions.

Scenario 1 – the Slovakian assumptions
To the degree possible with the difference in line items, this is an attempt to put the values from the study in the general model. Overhead is subsumed within general costs. Maintenance is included in depreciation. The total cost of administration is attributed to the Medfly aspect of the business. It is assumed that a similar level of administration would be needed whether tsetse production is initiated or not, as stated in the Slovakian proposal (Novotny *et al*., 2001).

An important difference in the general model framework is the inclusion of interest and capital repayment as a cost set within the same spreadsheet, so that these costs are reflected in the overall operating costs. This makes the profit line in this model appear much lower than in the Slovakian Operating Budget during the years the loan is being repaid. An additional line item for short-term credit is included to allow for cash flow shortages in the initial years, if and when needed.

Unit costs are calculated and averaged for the ten-year period, which would give an average unit cost of production of US$222/million in Scenario 1. At a proposed sale price of US$375/million this generates an expected cumulative profit of US$68.091 million over 10 years, with a net present value (NPV) at 7 percent discount of US$42.858 million. Break-even occurs in 2006 (year 3), with only 2005 showing a negative cumulative profit.

This scenario is in line with the presentation of the 5-year Operating Budget, extended to a 10-year horizon. It indicates a 69 percent profit, which is even higher than the Slovakian projection.

Scenario 2 – adding inflation of labour rates
Scenario 2 is presented to show the impact of changing one assumption. In this scenario, most assumptions continue to follow those put forth in Novotny *et al*. (2001). For example, the Slovakian assumption sets variable labour costs at almost one third the levels calculated based on international data (i.e. variable cost of the Slovakian assumption of 0.000 020 6 per million rather than 0.000 057 per million sales). This Case Study does not evaluate the original data, but notes this difference.

The significant change is that labour costs (both fixed and variable) are expected to increase as Slovakia moves to EU levels. This would have a major effect, with labour costs in the model increasing by 19.57 percent per year over ten years. Other cost inflation is not included in the model as it is assumed to remain in line with price inflation. So inflation in other costs and income would balance each other, but this would not be the case with labour.

In Scenario 2, in order to convert the variable labour cost to an equation dependent on the actual production, the cost of the first year's labour is actually less than shown in the Slovakian budget. Therefore, without any inflation factor, this figure would match the Slovakian budget by year 4.

Changing this one assumption, the average unit cost over 10 years would increase to US$260/million, which would still allow a profit of 44 percent from sales at US$375/million price and generate a net present value (NPV) of US$33.027. Although this inflation factor bring the annual cost for administration and for the variable labour line to a figure above that in the generic model (Section 7, Model Business Plan) the cumulative total over ten years remains lower for variable labour than is shown in the model.

In other words, applying the inflation factor for ten years does not appear to exaggerate the outcome for labour costs. Although it is impossible to predict what the inflation rate will be, it seems realistic to expect labour costs to rise more quickly than other costs in order to close the gap with the rest of Europe.

Scenario 3 – applying more international assumptions
Although the labour rates are left as in Scenario 2, Scenario 3 applies most of the other assumptions from the generic model. These changes include:

- No sales are expected in year 1 while the factory is being built and production equipment is being set up and tested.
- Fixed costs are assumed to begin from year 1, but a specific R&D budget (US$250 000/year) is included.
- The quality management line is increased to US$107 000/year.
- Slightly higher diet costs are used.
- Much higher costs are used for general supplies and transportation. (Both are increased approximately seven-fold compared to the assumptions in the Operating Budget.)
- The capacity of the factory is increased to 1132 million/week so that one-eighth of the potential capacity can be held in reserve, to ensure sales volumes are met during any production disruptions. (Increasing the capacity influences other costs that are based on a formula using capacity as the multiplier.)

However, the same overall capital cost is used, since the Operating Budget assumptions may already allow for reserve capacity in some other way. Also, the slightly lower costs for administration and variable labour are left, since the inflation makes up for this difference with the international model over time.

Changing all of these assumptions adds an extra cost of over US$30 million over 10 years and reduces the net return by US$34 million dollars on the assumption that a competitive unit price of US$375 per million would be required to maintain market share. The expected cumulative profit (still 11 percent) would fall to US$16.135 million. The NPV (7 percent discount) would be US$8.849 million for 10 years. Break-even occurs in year 6.

Again, this is not the application of all the assumptions from the generic model. When a higher variable labour cost is introduced into Scenario 3 (not shown here) so that labour costs match current Guatemala factory costs (US$57 per million sales instead of US$20 per million) then the NPV for 10 years is US$ –12.272 million (planned profit on sales = 0; price per million = US$443). When some planned profit is introduced then the proposed price increases rapidly e.g. a planned profit on sales of 10 percent on turnover increases the proposed price to US$487 per million which is more than one hundred dollars above the current competitive price of US$375. One reason this scenario is negative is the high initial capital cost of the facility.

Accepting that there are lower current costs for labour, Scenario 3 is considered more realistic in its assumptions than the first two scenarios.

Scenario 4 – international assumptions plus a lower initial cost
Scenario 4 is the same as Scenario 3 but assumes a lower capital cost for the factory. The cost used is based on the regression calculation on other international factory costs using a capacity of 1132 million per week (with actual peak output being 1000 million male Medfly per week). With this scenario, the Slovakian Operating Budget's capital cost of US$13.520 million is lowered to US$9.300 million.

Again, changing a single assumption has an important impact. This reduces the 10-year total capital repayment and interest costs by US$14 million. This brings average unit costs down to US$309/million and would allow sales at US$375/million with 22 percent profit on turnover.

This would result in an expected 10-year total profit of US$28.736 million and an NPV (7 percent discount) of US$18.024 million. Break-even would occur in year 4.

However, when Guatemalan labour prices are introduced as for Scenario 3 the NPV is reduced to US$–2.92 million (planned profit on sales = 0 percent; price per million = US$414). Any increase in planned profit would take the price to a level that would be even less competitive.

General comments on the Scenarios
Scenario 1 demonstrates the compatibility of the general model with the accounting plan used in the Slovakia study. The other scenarios illustrate the impact of alternative assumptions that may need to be addressed to make the plans more robust.

As long as the initially lower Slovakian labour rates are used, particularly for the variable labour, all four scenarios present a profit over ten years. If the higher international labour rate is used (as is used in the Model Business Plan), Scenarios 3 and 4, which apply more realistic assumptions on other factors, would both result in losses over ten years (e.g. NPV of US$ –12.272 and US$ –2.92 million respectively).

Table A1.5. Summary of assumptions applied and results of various scenarios in application of the financial model to the case of Slovakia

Assumptions applied	Capacity/ production (million per week)	Labour inflator	Profit level	Average cost[a]	Net present value (NPV)	10-year cumulative profit
					(US$ million)	
Scenario 1	1000/1000	–	69%	$222	$42.858	$68.091
Scenario 2	1000/1000	~20%	44%	$260	$33.027	$51.063
Scenario 3	1132/1000	~20%	11%	$337	$8.849	$16.135
Scenario 4	1132/1000	~20%	22%	$309	$18.024	$28.736
Model Business Plan (Section 7)	1100/972	6%	10%	$344	$6.535	$12.856

[a] Average cost is shown per 1 million male Medfly sold. Cost should not be confused with price charged.

In the full simulation version of the model, in which uncertainty functions are applied to all of the variables and the model is run over thousands of iterations, the effect of changes in the assumptions can be seen in the probability of achieving planned profits. The sensitivity of the model to variables was shown in a chart in Section 7. This showed that diet and labour costs were particularly sensitive variables, because they make up just over 50 percent of the total costs as presented from the general model assumptions shown in that Section. Therefore, particular attention should be paid to estimates of these variables.

Other assumptions can be tested with this model. It was demonstrated to the Slovakian Ministry of Agriculture in January 2002 to give the opportunity to consider the impact of variations in other factors.

A1.8 References

References in individual Annexes may have “a”, “b” etc. following the publication date, this refers to the way they appear in Section 9.1 References where all references are listed.

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8. Slovak Office of Standards, Metrology and Testing (OSMT, in Slovak UNMS), Stefanovicova 3, 814 39 Bratislava, Slovak Republic, Fax: (421-7) 391-050.

9. Mr. Miloslav Varga, Director, Department of Testing, Slovak Office of Standards, Metrology and Testing, telephone (421-7) 391-147, fax (421-7) 391-050, e-mail varga@unms.savba.sk.

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Slovakia Case Study Scenario 1

26/02/2002

This financial model is based on construction of a fixed capacity factory for Medfly, with loan capital.
Assumptions for the Slovakian figures appear in the text. Inflation/deflation not included in either costs or prices.

Item	Year 1	2	3	4	5	6	7	8	9	10	10-yr total
Production	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Sales (millions/week average per year)	250	500	750	1000	1000	1000	1000	1000	1000	1000	**8500**
Capital	All values below are in US$ million										
Capital outlay	*13.520*										***13.520***
Credit line interest cost		0.000	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.036**
Principal repayment		3.380	3.380	3.380	3.380	0.000	0.000	0.000	0.000	0.000	**13.520**
Interest cost on capital outlay		1.082	0.811	0.541	0.270	0.000	0.000	0.000	0.000	0.000	**2.704**
Opportunity cost		0.357	0.692	1.006	1.298	1.298	1.298	1.298	1.298	1.298	**9.843**
Depreciation	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	**13.520**
Fixed											
Administration	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	**1.164**
Utilities and communications	0.119	0.187	0.250	0.313	0.313	0.313	0.313	0.313	0.313	0.313	**2.748**
Insurance/security (loss & liability)	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	**1.721**
Research and development	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Quality management	0.021	0.032	0.035	0.037	0.037	0.037	0.037	0.037	0.037	0.037	**0.347**
Effluent management	0.017	0.035	0.052	0.069	0.069	0.069	0.069	0.069	0.069	0.069	**0.587**
Sales/promotion	0.000	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	**0.270**
Variable											
Insect diet	1.125	2.250	3.375	4.500	4.500	4.500	4.500	4.500	4.500	4.500	**38.250**
General supplies	0.088	0.171	0.254	0.337	0.337	0.337	0.337	0.337	0.337	0.337	**2.872**
Labour	0.515	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	**9.473**
Transportation	0.029	0.042	0.060	0.072	0.072	0.072	0.072	0.072	0.072	0.072	**0.635**
Total cost	**-3.554**	**-10.201**	**-11.611**	**-12.921**	**-12.942**	**-9.292**	**-9.292**	**-9.292**	**-9.292**	**-9.292**	**-97.689**
Income											
Sales at annual cost	*3.554*	*10.201*	*11.611*	*12.921*	*12.942*	*9.292*	*9.292*	*9.292*	*9.292*	*9.292*	***97.689***
Sales at 10-year average cost	*2.885*	*5.770*	*8.655*	*11.541*	*11.541*	*11.541*	*11.541*	*11.541*	*11.541*	*11.541*	***98.095***
Sales at 10-year average cost+profit	**4.876**	**9.752**	**14.628**	**19.504**	**19.504**	**19.504**	**19.504**	**19.504**	**19.504**	**19.504**	**165.780**
Cumulative income (inc profit) minus costs	***1.322***	***0.873***	***3.890***	***10.473***	***17.034***	***27.245***	***37.457***	***47.668***	***57.880***	***68.091***	**68.091**
Profit											
Annual net on sales	**1.322**	**-0.449**	**3.017**	**6.583**	**6.561**	**10.212**	**10.212**	**10.212**	**10.212**	**10.212**	**68.091**
Cumulative proportion on expenditure	*0.372*	*0.063*	*0.153*	*0.274*	*0.333*	*0.450*	*0.537*	*0.603*	*0.655*	*0.697*	*0.697*
Net present value (10 years) on profits $mn	**42.858**										

Variables values to set		
Capacity	(millions/week)	**1000**
Sales target proportion of capacity		**1.00**
Years to full sales		**4**
Interest rate		**0.08**
Opportunity cost rate		**0.08**
Repayment period on loan years		**5**
Depreciation period in years		**10**
Labour inflation rate		**0.00**
Planned profit on sales rate		**0.69**
Maximum competitive price/million		**0.000400**
Discount rate		**0.07**

	Fixed costs (annual per capacity)
Administration	**0.116**
Utilities and communications	**0.313**
Insurance/security (loss & liability)	**0.172**
Research and development	**0.000**
Quality management	**0.037**
Effluent management	**0.069**
Sales/promotion	**0.030**
Subtotal	*0.738*

Not used in Scenario 1

	Variable costs (per 1 million sales)
Insect diet	**0.000100**
General supplies	**0.000050**
Labour	**0.000020**
Transportation	**0.000010**
Subtotal	*0.000180*

Product cost and price	
On average 10 year sales/total cost	**0.000222**
Proposed price/million	**0.000375**

Slovakia Case Study Scenario 2

26/02/2002

This financial model is based on construction of a fixed capacity factory for Medfly, with loan capital.
Assumptions for the Slovakian figures appear in the text. Labour inflation/deflation is included costs and/or prices.

Item	**Year**										**10-yr total**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Production	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Sales (millions/week average per year)	250	500	750	1000	1000	1000	1000	1000	1000	1000	**8500**
Capital	All values below are in US$ million										
Capital outlay	*13.520*										***13.520***
Credit line interest cost		0.000	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.008**
Principal repayment		3.380	3.380	3.380	3.380	0.000	0.000	0.000	0.000	0.000	**13.520**
Interest cost on capital outlay		1.082	0.811	0.541	0.270	0.000	0.000	0.000	0.000	0.000	**2.704**
Opportunity cost		0.357	0.692	1.006	1.298	1.298	1.298	1.298	1.298	1.298	**9.843**
Depreciation	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	**13.520**
Fixed											
Administration	0.116	0.139	0.166	0.199	0.238	0.284	0.340	0.407	0.486	0.581	**2.958**
Utilities and communications	0.119	0.187	0.250	0.313	0.313	0.313	0.313	0.313	0.313	0.313	**2.748**
Insurance/security (loss & liability)	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	**1.721**
Research and development	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Quality management	0.021	0.032	0.035	0.037	0.037	0.037	0.037	0.037	0.037	0.037	**0.347**
Effluent management	0.017	0.035	0.052	0.069	0.069	0.069	0.069	0.069	0.069	0.069	**0.587**
Sales/promotion	0.000	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	**0.270**
Variable											
Insect diet	1.125	2.250	3.375	4.500	4.500	4.500	4.500	4.500	4.500	4.500	**38.250**
General supplies	0.088	0.171	0.254	0.337	0.337	0.337	0.337	0.337	0.337	0.337	**2.872**
Labour	0.260	0.622	1.115	1.778	2.126	2.541	3.039	3.633	4.344	5.194	**24.651**
Transportation	0.029	0.042	0.060	0.072	0.072	0.072	0.072	0.072	0.072	0.072	**0.635**
Total cost	**-3.299**	**-9.850**	**-11.753**	**-13.786**	**-14.194**	**-11.006**	**-11.559**	**-12.220**	**-13.010**	**-13.956**	**-114.633**
Income											
Sales at annual cost	*3.299*	*9.850*	*11.753*	*13.786*	*14.194*	*11.006*	*11.559*	*12.220*	*13.010*	*13.956*	***114.633***
Sales at 10-year average cost	*3.384*	*6.769*	*10.153*	*13.537*	*13.537*	*13.537*	*13.537*	*13.537*	*13.537*	*13.537*	***115.066***
Sales at 10-year average cost+profit	**4.873**	**9.747**	**14.620**	**19.494**	**19.494**	**19.494**	**19.494**	**19.494**	**19.494**	**19.494**	**165.695**
Cumulative income (inc profit) minus costs	***1.574***	***1.471***	***4.339***	***10.046***	***15.346***	***23.834***	***31.768***	***39.042***	***45.525***	***51.063***	**51.063**
Profit											
Annual net on sales	**1.574**	**-0.103**	**2.867**	**5.708**	**5.300**	**8.488**	**7.935**	**7.274**	**6.483**	**5.538**	**51.063**
Cumulative proportion on expenditure	*0.477*	*0.112*	*0.174*	*0.260*	*0.290*	*0.373*	*0.421*	*0.445*	*0.452*	*0.445*	*0.445*
Net present value (10 years) on profits $mn	**33.027**										

Variables values to set		
Capacity	(millions/week)	**1000**
Sales target proportion of capacity		**1.00**
Years to full sales		**4**
Interest rate		**0.08**
Opportunity cost rate		**0.08**
Repayment period on loan years		**5**
Depreciation period in years		**10**
Labour inflation rate		**0.19566**
Planned profit on sales rate		**0.44**
Maximum competitive price/million		**0.000400**
Discount rate		**0.07**

	Fixed costs (annual per capacity)
Administration	**0.116**
Utilities and communications	**0.313**
Insurance/security (loss & liability)	**0.172**
Research and development	**0.000**
Quality management	**0.037**
Effluent management	**0.069**
Sales/promotion	**0.030**
Subtotal	*0.738*

Not used in Scenario 2	**Variable costs (per 1 million sales)**
Insect diet	**0.000100**
General supplies	**0.000050**
Labour	**0.000020**
Transportation	**0.000010**
Subtotal	*0.000180*

Product cost and price	
On average 10 year sales/total cost	**0.000260**
Proposed price/million	**0.000375**

Slovakia Case Study Scenario 3

26/02/2002

This financial model is based on construction of a fixed capacity factory for Medfly, with loan capital.
Inflation/deflation not included in either costs or prices, except for labour/wage rates (enter as a variable) to allow for these exceeding general inflation in some cases.

Item	Year 1	2	3	4	5	6	7	8	9	10	10-yr total
Production	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Sales (millions/week average per year)	0	500	750	1000	1000	1000	1000	1000	1000	1000	**8249**
Capital	All values below are in US$ million										
Capital outlay	*13.520*										***13.520***
Credit line interest cost		0.173	0.181	0.010	0.000	0.000	0.000	0.000	0.000	0.000	**0.364**
Principal repayment		3.380	3.380	3.380	3.380	0.000	0.000	0.000	0.000	0.000	**13.520**
Interest cost on capital outlay		1.082	0.811	0.541	0.270	0.000	0.000	0.000	0.000	0.000	**2.704**
Opportunity cost		0.357	0.692	1.006	1.298	1.298	1.298	1.298	1.298	1.298	**9.843**
Depreciation	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	**13.520**
Fixed											
Administration	0.116	0.139	0.166	0.199	0.238	0.284	0.340	0.407	0.486	0.581	**2.958**
Utilities and communications	0.060	0.119	0.187	0.250	0.313	0.313	0.313	0.313	0.313	0.313	**2.495**
Insurance/security (loss & liability)	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	**1.721**
Research and development	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	**2.500**
Quality management	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	**1.070**
Effluent management	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	**0.690**
Sales/promotion	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	**0.300**
Variable											
Insect diet	0.000	2.600	3.900	5.200	5.200	5.200	5.200	5.200	5.200	5.200	**42.897**
General supplies	0.000	1.300	1.950	2.600	2.600	2.600	2.600	2.600	2.600	2.600	**21.449**
Labour	0.000	0.622	1.115	1.778	2.125	2.541	3.038	3.633	4.344	5.194	**24.390**
Transportation	0.000	0.260	0.390	0.520	0.520	0.520	0.520	0.520	0.520	0.520	**4.290**
Total cost	**-2.157**	**-12.010**	**-14.752**	**-17.463**	**-17.924**	**-14.736**	**-15.289**	**-15.950**	**-16.741**	**-17.686**	**-144.709**
Income											
Sales at annual cost	*0.000*	*12.010*	*14.752*	*17.463*	*17.924*	*14.736*	*15.289*	*15.950*	*16.741*	*17.686*	***142.552***
Sales at 10-year average cost	*0.000*	*8.774*	*13.161*	*17.548*	*17.548*	*17.548*	*17.548*	*17.548*	*17.548*	*17.548*	***144.774***
Sales at 10-year average cost+profit	**0.000**	**9.748**	**14.622**	**19.496**	**19.496**	**19.496**	**19.496**	**19.496**	**19.496**	**19.496**	**160.844**
Cumulative income (inc profit) minus costs	***-2.157***	***-4.419***	***-4.549***	***-2.516***	***-0.944***	***3.816***	***8.023***	***11.569***	***14.324***	***16.135***	**16.135**
Profit											
Annual net on sales	**-2.157**	**-2.262**	**-0.130**	**2.033**	**1.572**	**4.760**	**4.207**	**3.546**	**2.756**	**1.811**	**16.135**
Cumulative proportion on expenditure	*-1.000*	*-0.312*	*-0.157*	*-0.054*	*-0.015*	*0.048*	*0.085*	*0.105*	*0.113*	*0.111*	*0.111*
Net present value (10 years) on profits $mn	**8.849**										

Variables values to set		
Capacity	(millions/week)	**1132**
Sales target proportion of capacity		**0.88**
Years to full sales		**4**
Interest rate		**0.08**
Opportunity cost rate		**0.08**
Repayment period on loan years		**5**
Depreciation period in years		**10**
Labour inflation rate		**0.19566**
Planned profit on sales rate		**0.11**
Maximum competitive price/million		**0.000400**
Discount rate		**0.07**

	Fixed costs (annual per capacity)
Administration	**0.116**
Utilities and communications	**0.313**
Insurance/security (loss & liability)	**0.172**
Research and development	**0.250**
Quality management	**0.107**
Effluent management	**0.069**
Sales/promotion	**0.030**
Subtotal	*1.058*

	Variable costs (per 1 million sales)
Insect diet	**0.000100**
General supplies	**0.000050**
Labour	**0.000020**
Transportation	**0.000010**
Subtotal	*0.000180*
Product cost and price	
On average 10 year sales/total cost	**0.000337**
Proposed price/million	**0.000375**

Slovakia Case Study Scenario 4

26/02/2002

This financial model is based on construction of a fixed capacity factory for Medfly, with loan capital.
Inflation/deflation not included in either costs or prices, except for labour/wage rates (enter as a variable) to allow for these exceeding general inflation in some cases.

Item	**Year**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10-yr total**
Production	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Sales (millions/week average per year)	0	500	750	1000	1000	1000	1000	1000	1000	1000	**8249**
Capital	All values below are in US$ million										
Capital outlay	*9.300*										***9.300***
Credit line interest cost		0.139	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.163**
Principal repayment		2.325	2.325	2.325	2.325	0.000	0.000	0.000	0.000	0.000	**9.300**
Interest cost on capital outlay		0.744	0.558	0.372	0.186	0.000	0.000	0.000	0.000	0.000	**1.860**
Opportunity cost		0.246	0.476	0.692	0.893	0.893	0.893	0.893	0.893	0.893	**6.770**
Depreciation	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	**9.300**
Fixed											
Administration	0.116	0.139	0.166	0.199	0.238	0.284	0.340	0.407	0.486	0.581	**2.958**
Utilities and communications	0.060	0.119	0.187	0.250	0.313	0.313	0.313	0.313	0.313	0.313	**2.495**
Insurance/security (loss & liability)	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	**1.721**
Research and development	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	**2.500**
Quality management	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	**1.070**
Effluent management	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	**0.690**
Sales/promotion	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	**0.300**
Variable											
Insect diet	0.000	2.600	3.900	5.200	5.200	5.200	5.200	5.200	5.200	5.200	**42.897**
General supplies	0.000	1.300	1.950	2.600	2.600	2.600	2.600	2.600	2.600	2.600	**21.449**
Labour	0.000	0.622	1.115	1.778	2.125	2.541	3.038	3.633	4.344	5.194	**24.390**
Transportation	0.000	0.260	0.390	0.520	0.520	0.520	0.520	0.520	0.520	0.520	**4.290**
Total cost	**-1.735**	**-10.051**	**-12.649**	**-15.493**	**-15.958**	**-13.909**	**-14.462**	**-15.123**	**-15.914**	**-16.859**	**-132.151**
Income											
Sales at annual cost	*0.000*	*10.051*	*12.649*	*15.493*	*15.958*	*13.909*	*14.462*	*15.123*	*15.914*	*16.859*	***130.417***
Sales at 10-year average cost	*0.000*	*8.025*	*12.038*	*16.051*	*16.051*	*16.051*	*16.051*	*16.051*	*16.051*	*16.051*	***132.418***
Sales at 10-year average cost+profit	**0.000**	**9.751**	**14.626**	**19.502**	**19.502**	**19.502**	**19.502**	**19.502**	**19.502**	**19.502**	**160.887**
Cumulative income (inc profit) minus costs	***-1.735***	***-2.034***	***-0.057***	***3.951***	***7.495***	***13.087***	***18.127***	***22.505***	***26.093***	***28.736***	**28.736**
Profit											
Annual net on sales	**-1.735**	**-0.300**	**1.977**	**4.009**	**3.544**	**5.592**	**5.039**	**4.378**	**3.588**	**2.643**	**28.736**
Cumulative proportion on expenditure	*-1.000*	*-0.173*	*-0.002*	*0.099*	*0.134*	*0.188*	*0.215*	*0.226*	*0.226*	*0.217*	*0.217*
Net present value (10 years) on profits $mn	**18.024**										

Variables values to set		
Capacity	(millions/week)	**1132**
Sales target proportion of capacity		**0.88**
Years to full sales		**4**
Interest rate		**0.08**
Opportunity cost rate		**0.08**
Repayment period on loan years		**5**
Depreciation period in years		**10**
Labour inflation rate		**0.19566**
Planned profit on sales rate		**0.22**

Fixed costs (annual per capacity)	
Administration	**0.116**
Utilities and communications	**0.313**
Insurance/security (loss & liability)	**0.172**
Research and development	**0.250**
Quality management	**0.107**
Effluent management	**0.069**
Sales/promotion	**0.030**
Subtotal	*1.058*

Variable costs (per 1 million sales)	
Insect diet	**0.000100**
General supplies	**0.000050**
Labour	**0.000020**
Transportation	**0.000010**
Subtotal	*0.000180*
Product cost and price	
On average 10 year sales/total cost	**0.000309**

A1.9 Appendix: Doing business in Slovakia

A1.9.1 Taxes and duties in Slovakia

Customs duty:
This varies according to the product or service being imported. The customs duty is assessed on the cost, insurance and freight (CIF) of the product, as listed on its invoice. From December 21, 1998, all foreign postal shipments and commercial courier shipments with a customs value equal to or less than 1000 SKK[21] (about US$ 26) addressed to domestic recipients are exempted from entrance duty, value-added tax, EXIMBANK (Export-Import Bank of the United States) surcharge, foreign trade support fund surcharge and certification requirements.

Import tax:
According to the customs act, there are 3 types of customs duty, which in turn influence the tariff used. (i) General, (ii) Agreed (WTO members and bilateral commercial agreements) and (iii) Preferential (general system of preferences or international agreements on customs union or free trade zone). The import duty is calculated according to the customs value of the goods, including freight and insurance from point of loading to the border of the Slovakian Republic. One caveat is that there has been in the past a surcharge (percentage) on goods being imported where there is already an industry within Slovakia, which makes that product/service. However at present this is not the case. The general rate usually stands at about 5 percent of the CIF.

Value added tax (VAT):
Payable at the point of entry. It is assessed once again on the CIF value plus the customs duty. There are differing rates such as lower preferential (usually food, and perishable consumer goods), basic rate (22 percent), a few goods are not subject to VAT such as medicine.

Exemptions from taxes and duties:
Customs duty is negated on products imported as a non-cash contribution (machinery and equipment – excepting items such as personal vehicles) of foreign entity into manufacturing operations of a commercial company based in the Slovak Republic. This only occurs if the foreign entity has at least a 35 percent stake in the registered Slovak manufacturing company and the non-cash contribution totals at least 10 million SKK (about US$210 000).

Income tax:

Individual -	38 percent (10 percent for the general health insurance, 25 percent for the social security fund, and 3 percent for the unemployment fund).
Corporate (on profits) -	40 percent.
	Withholding - 15-25 percent (in general, but often 5 percent in the case that a foreign parent company owns more than 25 percent of the Slovak company's equity capital). Levied on dividends, capital gains and other income paid to non-residents.

[21] The Slovakian koruna, or *slovenská koruna*, represented by SKK, replaced the Czechoslovakian koruna in 1993 and will be replaced by the € in approximately 2009.

Property tax and property transfer tax:
Up to 20 percent (based on area).

Sales and excise taxes:
VAT - 23 percent on most goods (10 percent on some goods).

Effective tax rate on foreign investment:
(a). Manufacturing
Regular taxable case - 39.1%
Holiday incentives - 35.4%
Tax holidays - 16.9%
(b) Services
Regular taxable case - 37.4%
Holiday incentives - 34.0%
Tax holidays - 26.5%

Tax incentives:
Slovakia provides a 5-year corporate income tax holiday allowing for a 100 percent reduction in taxes and a conditional extension for 5 years that allows for a 50 percent reduction in corporate tax. Tax holidays were recently introduced in the Czech Republic (1-5 years) and Hungary (5 to 10 years), while Poland and Slovenia have no tax holidays. All five countries offer other tax incentives for investment including accelerated depreciation, investment tax credits and/or investment allowances. (Excerpt from reference 14).

The above tax information was sourced from the Slovakian embassy website in London (references 13, 14).

A1.9.2 Labour availability and costs

According to the Guide to the Slovakian Republic, foreign investors have found the Slovaks represent "a top quality work force that are efficient and productive". There is no problem finding skilled engineers and managers, due to the higher education system, which turns out 75 000 new specialists every year (reference 1). This confirms the statements in the feasibility study.

The minimum wage in the Slovak Republic in October 2001 was 4920 SKK (approx. US$101) per month. In 2000, corporate managers average gross monthly wage was 40 741 SKK (US$842), and for general managers 34 282 SKK (US$781) over the same period. (Ivan Chrappa, pers. comm. (references 2, 4))

According to the Economic and Financial Data for the Slovak Republic, the overall average monthly wages per employee from the second quarter in 2001 was 12 064 SKK, up from 11 315 SKK in the previous quarter. At the current exchange rate of 48.33 SKK to US$1 makes an equivalent of US$249.61 per month (reference 2). Unemployment stands at around 16 percent (reference 1).

However, other less reliable sources describe the average wage as nearer US$400 per month (Guide to the Slovakian Republic www.slovakia.org).

The cost of labour is extremely important due to the sensitivity of the financial model to this item, second only to the insect diet. The first scenario assumes the labour costs presented in the study with no inflation (for the larger facility, no information is available on the operating expenses for the pilot project). The second scenario uses labour costs that are inflating with the changes anticipated as Slovakia becomes a member of the European Union. Although it is impossible to know how quickly labour rates will rise, there are reasons to believe that they will go up to meet the lower levels of pay that exist currently within the EU.

The members of the EU have continued to have a wide range in minimum wage up to 2001. With the harmonization of such figures under the Euro, it is believed that competition for workers will increase and employees in the lower paid countries will demand parity (reference 17). Under these conditions, Slovakia may face high inflation and an increase in wages comparable to those of Portugal or Spain, two of the lowest paying countries in the EU well below the EU average. Minimum wage employees account for a large part of the labour costs for such a large facility as that proposed in Slovakia. These other scenarios, therefore, lead to very different bottom lines.

Year	Euros
0	0.35
1	0.418 481
2	0.500 361
3	0.598 262
4	0.715 318
5	0.855 278
6	1.022 622
7	1.222 708
8	1.461 943
9	1.747 988
10	2.09

Working in Euros (€), the minimum hourly wage of €0.35 is assumed for Slovakia (this is the 2001 average for Eastern Europe). The level that Slovakia is expected to reach in the ten years from 2004 to 2013 is that of Portugal's hourly minimum wage in 2001, €2.09. To reach this in that time period (10 years), the inflation rate for labour will be an annual 19.566 03 percent. This set of assumptions is somewhat arbitrary, but representative of what will occur.

Considering that the project will also be providing an important source of employment at the location chosen, and that it may also provide a critical back up for tsetse production, lower returns due to higher labour rates may still satisfy the requirements of the investors. This is particularly the case if the Government participates.

One way in which the Government can acknowledge the contribution of the project is through the National Labour Agency's non-refundable subsidy that is described in the study (pages 54-55). If this programme continues, 200 new jobs will result in 100 000 SKK per employee after one year of employment if the region suffers from 20-25 percent unemployment. This will potentially total 20 million SKK for the business, to be paid out in 10 000 SKK /per employee monthly instalments. This translates into an income of US$413 822 in year 2 at the current exchange rate (48.33 SKK/US$1). This can be entered into Scenario 1 and 2 if the Slovakian Team believes it is reliable income.

The Slovakia proposal showed the cost of this labour as static (no increase in minimum wage) over the time projected. In the test, the cost of labour was set to match the level of Portugal, simply as another member of the EU with lower wages, which required an increase of the rate of over 19% per year. In fact, in the 4 years up to 2005, the increase was closer to 9% (reference 18). This new data now allows the manager to alter the assumption in less than a minute and see the impacts of that change.

A1.9.3 Logistics details for imports to and exports from Slovakia (2001)

Import documentation:
Legislation harmonized with EU standards and the invoice with the goods is part of the declaration. If the lower rate of customs duty applies (usually for goods that are exported from the EU) then evidence of their place of origin is required, shipping documents, invoices or other. These documents should display values and weights of the goods and usually certified by the country of origin (e.g. U.S. Chambers of Commerce). Slovak importers must have the original documents at the time the shipment arrives at Slovak customs.

Import licenses:
Official licenses – required for the import of some goods/services. For information, contact the Ministry of the Economy of the Slovak Republic who issue the licenses (reference 7). Products, which need licenses, fall into 2 categories, “general” – (where the license obtained is a formality) and “specific” – where the goods are pharmaceuticals, weapons or Coordinating Committee for Multilateral Export Controls (COCOM) items.

Export licenses:
The Slovak Chamber of Commerce and Industry (SCCI) is the national issuing association for a unified customs document Admission Temporaire (ATA) carnet, which enables temporary goods export/import based on SCCI guarantee. There is no obligation on the document holder’s side to pay a customs debt and customs charges in the country of destination (reference 12).

Exports are not subject to tax (exports are zero-rated in that the firm can claim input tax credits for taxes paid on purchases from other registered businesses) (reference 13).

Standards and quality control:
Goods to be imported require certificates issued from the Slovak Authorities (Office of Standards, Metrology and Testing (OSMT) and National testing centres (references 8, 9)) to attest the quality and standard of the merchandise.

The information sources for the above were from the websites of the Embassy for the Slovak Republic Commercial department (reference 11) and Market Access information (reference10) and can be described as accurate.

Annex 2
On-site study of market for sterile Medfly in Portugal

The assumptions in the original study remain true. The current situation in the Algarve presents an even stronger case for adopting SIT, due to increasing production area. Although Portugal was first in Europe with its SIT programme in Madeira, the country is now being surpassed by Valencia, Spain. Regional production of sterile Medfly males has increased considerably, while international sources remain in place for any shortfalls. Yet, producers in continental Portugal continue to be slow in committing to SIT. Several important pesticides for Medfly control are being eliminated under the EU-wide review of active ingredients, which may provide the turning point for initiating a large scale SIT programme.

A2.1 Introduction

This market study is intended to assess the potential number of sterile Medfly that could be used in a control programme in Portugal. It is based on the assumption that the market would be for a continuous suppression campaign in selected areas of the country due to the continued presence of Medfly in neighbouring areas in other parts of Portugal, Spain and Morocco. It also assumes that any use of the sterile insect technique (SIT) would be managed through substantial area-wide programmes with a mix of public and private involvement. It addresses issues of location, scale and timing of possible SIT programmes in Portugal.

Portugal is divided into seven agricultural regions: Algarve, Alentejo, the Ribatejo & Oeste (which is divided into 2 sub-regions, the Ribatejo and the Oeste), Beira Litoral, Beira Interior, Tras-Os-Montes and Entre-Douro & Minho (Figure A2.1). (The Azores and Madeira are not shown.).

FIG. A2.1. Agricultural regions of Portugal.

There is concern throughout Portugal about the damage caused by Medfly as well as the cost and environmental impact of current pesticide control. Market pressures to reduce pesticide use due to the European Commission (EC) regulations that limit residues and increasingly stringent quality requirements from the retail industry. This has resulted in a joint EC/Portuguese funded Medfly suppression programme on the island of Madeira (Madeiramed), operational since 1996. Also, in the Algarve, an area of particular concern due to the high number of cover spray applications against Medfly, a regional project to assess the feasibility of SIT was implemented (Algarve-Med). The project "Medfly problem in the Algarve and its control using SIT" was developed within the framework of the European Community programme **INTERREG II,** for cross border co-operation, financed under the European Regional Development Fund (ERDF) and carried out in collaboration by the Algarve Regional Department of Agriculture, the University of the Algarve, the Madeiramed programme and the Department of Agriculture of Andalucia. Baseline field data on Medfly populations essential for a SIT programme have been collected in the Algarve since March 2000. The results of the Algarve-Med project completed in 2001, confirmed the viability of SIT in the Algarve (Passos de Carvalho, 2001). Further proposals for Medfly control are under consideration in the Azores.

This analysis examined climatic conditions and fruit production to determine a spatial estimate of areas with high benefit from area-wide Medfly control. This is based on data from the Portuguese meteorological service and fruit production data supplied by the Department of Agriculture for each concelho or freguesia (local government districts). A combined assessment of Medfly abundance and potential damage is presented in map form.

Two regions of Portugal are likely areas for implementation of area-wide Medfly control – Algarve (in the south) and Ribatejo & Oeste (north and northeast of Lisbon). Implementation of SIT suppression in the Algarve is considered in more detail because there has already been action towards implementation. Three potential implementation schemes are presented. Uptake in the Oeste and Ribatejo regions would be likely to follow several years after the Algarve and demand would likely be stimulated by SIT success in the south. Control in the Oeste and Ribatejo may be more difficult to organize since the area has more dispersed commercial host areas than the Algarve.

A2.2 Overview of Medfly problem in Portugal

The maps indicate the relative abundance of Medfly and the damage potential. Figure A2.2 indicates relative production of commercial hosts with severe Medfly attack. In Figure A2.3, these are combined in the larger map, which couples production and climatic potential to give an estimate of the potential damage

An area-wide Medfly SIT programme would be feasible in the two areas with the highest damage potential: the Oeste/Ribatejo and the Algarve. The Medfly is more abundant in the south, but fruit production is greater in the west. Citrus is severely attacked by Medfly; highest production areas are in the Algarve, with substantial but declining areas in the Ribatejo. Stone fruit is also severely attacked by Medfly; highest production areas are in the Ribatejo. Areas have declined in the Ribatejo since 1989, but production on the remaining areas has intensified, maintaining total production levels.

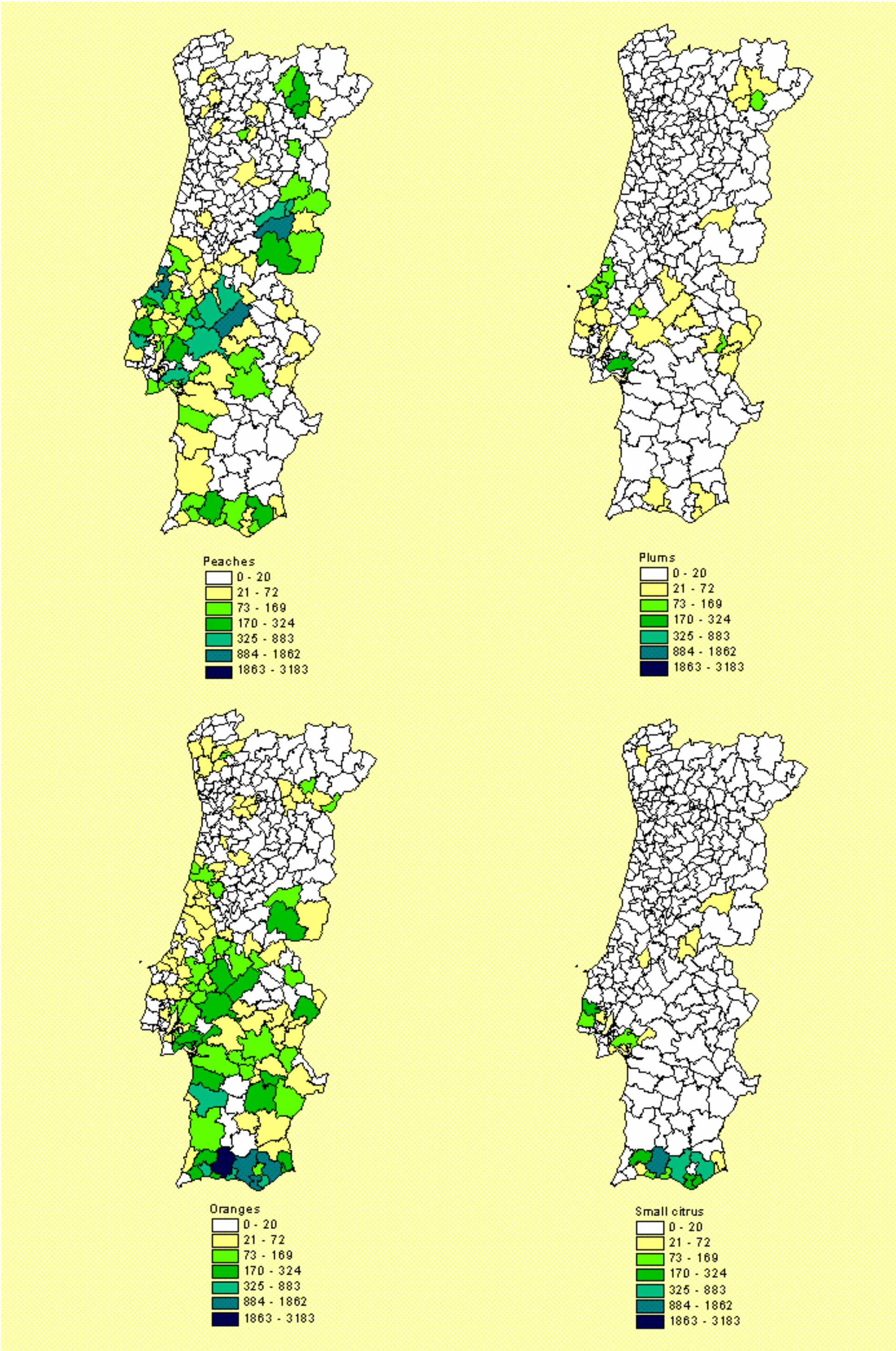

FIG. A2.2. Maps of stone fruit and citrus production projected from 1989 and 1999 agricultural census data (source: INE,) in hectares per district.

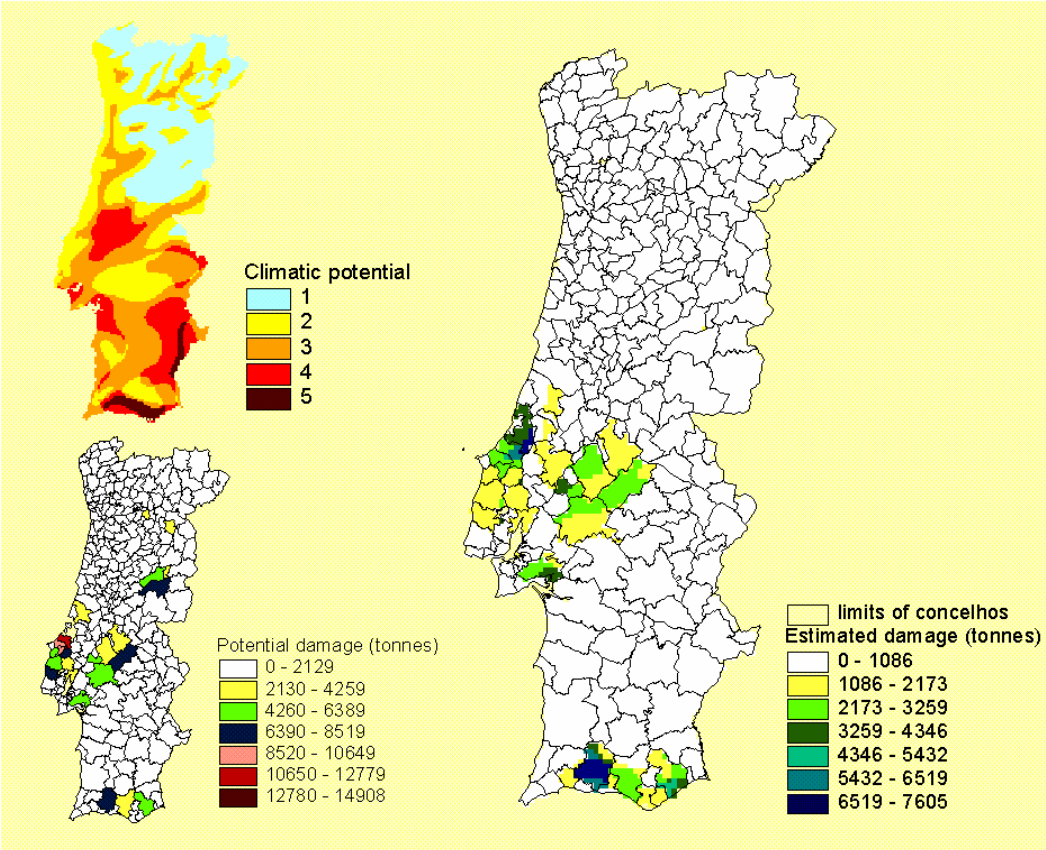

FIG. A2.3. Climatic potential (1=low, 5=high) combined with production (shown as mt per district) highlights the areas in Algarve, Oeste and Ribatejo that may be suited to Medfly SIT management (from Larcher-Carvalho, 2002).

The maps in Figure A2.3 show, first, the climatic map alone (top left), and, then, the fruit production (bottom left). The larger map couples production and climatic potential to give an estimate of the potential damage (in mt per year per district). Potential damage is as high as 30-100% (citrus-peaches, respectively) in the peak months in the most severe districts, and residual losses (despite control efforts) are estimated to be up to 5-8 percent (citrus-peaches) in high intensity orchards. These losses are very serious and warrant improved control.

The Algarve has two areas of high damage concentration, around Silves (7500 ha commercial hosts) and Tavira (4700 ha commercial hosts); in the Ribatejo and Oeste there are also two areas, around Alcobaça (25 000 ha) and further inland along the southeast bank of the Tagus in the Ribatejo (up to 75 000 ha).

A2.3 Medfly in the Algarve

Within Portugal, it is in the Algarve that Medfly finds the best conditions for its reproduction and development and it is where it poses the most serious threat to fruit production. This is mainly due to the favourable weather conditions, poor phytosanitary practices and the existence of a wide range of hosts that mature all year round (Carvalho and Pereira, 1994). Medfly is well established in the Algarve although there are no data as to the evolution of the population throughout the years (Carvalho, interview). Medfly can have five to eight generations per year (Guerreiro *et al.*, 1998).

According to Entrudo (1955), the first Medfly adults are caught around April. This initial population attacks citrus until mid May. Adult populations start increasing in June/July and keep fairly constant until August. Population fluctuations in this period are mainly related with availability of apricots and peaches. The populations peak from the mid/end of August to mid/end October (Guerreiro *et al.*, 1998).

Carvalho and Pereira (1994) state that adults can be found throughout the year. An analysis of the distribution of temperature and relative humidity indicates that the Algarve has favourable conditions for Medfly all year round. However, as the results of the monitoring programme run by Algarve-Med show, the population numbers are extremely small during January, February and March. The flight data obtained by the monitoring team of Algarve-Med, monitoring since March 2000, is fairly consistent with the previous studies. Most flies are caught from mid-September to December.

Fruit production occupies an important place in the economy of the Algarve region. It contributes 38.8 percent to the gross agricultural production (Jesus, 1993). A wide range of other Medfly hosts is also grown in the Algarve. These include: oranges and small citrus, apricots, peaches, figs, plums, loquats, grapes, persimmon, quinces, pomegranates, roses, strawberry tree, apple, pear, passion fruit and sub-tropical fruits (custard pear, avocado, mango and guavas). Most of these fruit trees are also present in backyard gardens that occupy an area estimated at around at around 1359 ha (Guerreiro *et al.*, 1998) and act as a reservoir for Medfly during the winter (Rui Pereira, interview).

Citrus is the most important of all fruit crops, occupying around 17 700 ha (Instituto Nacional de Estatística, 2004). The area of citrus has been increasing for the last 40 years. From 1994 to 1997, it increased at a rate of 500 ha per year. In the past 20 years, the yields have increased three-fold. In 1997/98, citrus production was estimated at 250 000 mt of which oranges accounted for 150 000 mt (Valencia Late and D. João are the most important citrus varieties followed by Baia and Dalmau (Madeira, 1995), clementines for 50 000 mt, tangerines Encore for 30 000 mt and other citrus for 20 000 mt (Guerreiro *et al.*, 1998). Citrus occupies 10 percent of the agricultural area (Madeira, 1995), which represents 70 percent of the total national citrus production and 30 percent of the regional agricultural gross product (Freitas *et al.*, 1998).

Table A2.1. Area of Medfly hosts in the Algarve (INE, 2004)

Hosts	Algarve
Orange	13 458
Other citrus	4 245
Apricot	206
Peaches	515
Figs	2 961
Pear	84
Plum	101
Apple	27
Exotic	192
Host area (ha)	**21 789**

Citrus is present in the market all year round due to the existence of different orange varieties that mature at different times. There is a balance between early maturing oranges (October/April) and late maturing oranges (April/September). A few small citrus varieties are harvested from the end of April to mid-October. Although there are tangerines from October to June, 50 percent of the tangerine production is concentrated between November and January. Total citrus production is therefore concentrated in autumn/winter (Madeira, 1995).

Medfly is one of the most important citrus pests despite the fact that the egg and larval mortality rate is as high as 97 percent. This is due firstly to the high economic importance of citrus in the Algarve, secondly, to the fact that Medfly is one of the few pests that manage to develop inside the citrus fruit causing extensive damage and thirdly to the high population levels during the period of maturation of citrus (Carvalho and Fernandes, 1996).

The level of damage varies with factors such as variety, maturation date, harvest date and control methods used. Early maturing varieties are heavily attacked. The Dalmau, for example, which matures around September/October, is heavily attacked. This variety is probably not important commercially due to Medfly (Rui Pereira, interview). However, many of the traditional varieties are being replaced with early maturing ones such as the Newhall, and problems have been increasing (Carvalho and Pereira, 1993).

Another problem is that the harvest is very often delayed because there is less competition from Spanish oranges towards the end of the season and market prices are higher. Valencia Late, which is expanding in Portugal, is one of the varieties that stays on the tree for as long as possible, resulting in an increase in Medfly attacks. For example, in 1998, the fruits stayed on the tree until December (Silvino Oliveira, interview). However, in Andalucia (Spain), the Valencia Late is harvested before the fruit is stung (Carvalho, interview). Even if harvested earlier the damage caused by Medfly in this variety is already quite high.

Guerreiro *et al.* (1998) estimate that 1.5 percent is the loss in more intensive orchards, where five insecticide treatments are carried out, with 3 percent losses in less intensive orchards where only two treatments are carried out typically.

Apricots are grown commercially only in the Algarve and Ribatejo & Oeste (Silva and Oliveira, 1985). The area of apricots increased greatly in the 1950s and, because of their dispersion, they caused the increase in the area of distribution of Medfly. Apricots have an important role in the maintenance of Medfly populations as they are one of the first crops to mature. The damage is severe because the sting causes a violent reaction. A red patch develops which causes total loss of commercial value. As with peaches, late maturing varieties have to be avoided because the intensity of the attacks is very high (Carvalho and Pereira, 1993). It has also been reported that in previous years early maturing varieties have been heavily attacked due to high populations coming from citrus and loquats (Entrudo, 1955). This crop could be very beneficial for the Algarve but farmers do not want to grow it any more because of Medfly (Carvalho, interview).

The area of peaches has been decreasing due to subsidies to abandon this crop (Gabinete de Planeamento e Política Agro-Alimentar, 1997). However, it is still an important fruit crop in the Algarve occupying almost 500 ha. Medfly is one of the reasons for the decline of peach production in the Algarve. Peaches and apricots suffer most damage from Medfly. If peaches are left untreated, all the fruits can be lost. Early maturing varieties have to be chosen to escape Medfly (Rui Pereira, interview). No late maturing peaches can be grown in the region because the number of treatments required to treat Medfly would be too high (Carvalho, interview).

There are almost 3000 ha of figs in the Algarve. The area of figs has also been decreasing but, in some cases new orchards with figs for fresh consumption, following more modern cultural techniques (trees planted closer together for example), are being planted (Rui de Sousa, interview). There are two main groups of figs: "Lampos" and "Vindímos". The Lampos are only for fresh consumption whilst the Vindímos are for fresh and dry consumption. Fresh figs have higher value.

If the attacks start early, damage can be quite high in fresh figs. However, figs are not usually treated with pesticides and damage is not valued (Rui Pereira, interview). Because populations are not controlled, figs act as a reservoir allowing the increase of populations that will afterwards attack other crops (Carvalho, interview). Severe damage can also occur when the population peaks in September/October.

The attack in figs varies according to the characteristics of the area where they are grown. For example, no damage has been observed in fruits grown on the slopes of mountains. In areas with low humidity, the attacks are almost negligible but if the figs are in irrigated areas or areas with higher humidity, the attacks are higher. The increase in irrigated areas has caused an increase in Medfly infestation in figs. With higher humidity, the trees develop more and provide better sheltering conditions and fruits with more water content favouring Medfly infestations (Entrudo, 1955). Entrudo (1955) found 73 percent of the fruits infested and an average of 16.2 larvae per fruit.

The area of plums is small and has been decreasing due to marketing difficulties. Late maturing varieties of plum are most at risk, the Chinese variety being one of the most heavily attacked (Carvalho, interview). The area of exotic fruits is still small in the Algarve but the Ministry of Agriculture believes the Algarve has favourable conditions for growing such fruits. It is in fact an alternative crop for some citrus producers (Gabinete de Planeamento e Política Agro-Alimentar, 1997). So far, these fruit crops occupy an area of around 120 ha. Damage in grapes, persimmons, loquats, "medronheiro" (*Arbutus unedo*), quinces, pomegranates and roses is less important.

A2.4 Medfly in the Ribatejo & Oeste

The abundance of Medfly in the Ribatejo & Oeste is much less than in the south due to the climate and type of host. Controls are applied significantly less frequently in orchards in these regions, but production is higher, so the absolute level of damage in similar to Algarve. In the Oeste pome fruits predominate, and are less susceptible to attack, so demand is likely to be much less in this region. While orchard areas have declined in the Ribatejo, production has been maintained. This results in lower density of orchard areas compared to non-commercial hosts. In both sub-regions, Ribatejo and Oeste, the total area that would need to be treated with SIT to include the main host production would be much higher than the orchards themselves, around 400 000 ha in the Ribatejo and 215 000 ha in the Oeste.

A2.5 Current control

Current control methods usually consist of high doses of dimethoate or fenthion in ground applied cover sprays on a calendar basis. In the Algarve for citrus, treatments start in March/April and go on until the end of the summer. Spraying is carried out every 15 days or every three weeks from the moment the Medfly is detected (Silvino Oliveira, interview). An average of five to ten treatments are applied to control Medfly in Algarve (Carvalho, interview), with two to five in the west.

In peaches in the Algarve, treatments start in the beginning of May and they are repeated every ten days or even weekly until harvest (Carvalho, Rui Pereira, interview). The average number of treatments is six (Guerreiro *et al.*, 1998). Sometimes 15 to 20 treatments are carried out (Rui Pereira, interview).

The frequency of treatments and the quantities of pesticide applied are many times higher than they should be. In their decision to treat, farmers are influenced by neighbours or also by traders who demand that treatments should be made. The total quantity of dimethoate used in the Algarve region is estimated at around 50 000 kg (Guerreiro *et al.*, 1998).

However, many orchards are low input and the number of applications is much reduced. The manager of the cooperative Cooperativa Agricola de Citricultores do Algarve (CACIAL, which has 90 members) estimates that farmers with areas less than 8 ha do not treat (Horácio Ferreira, interview). Farmers belonging to Integrated Pest Management (IPM) Associations follow more reduced input control strategies. These farmers, or the Association's technician, monitor the pest and spray only when the economic injury level of one fly/trap/day or 2-3 percent of damage fruits is reached (Guerreiro *et al.*, 1998).

The excessive use of pesticides can cause toxicological, environmental and economic problems. The residues accumulate in the peel of the fruit posing a risk to the consumer. In citrus, a much higher level of residues accumulates due to the characteristics of the peel causing serious problems when the peel is used for soft drinks, jams and oils (Silva Fernandes, 1994). Residues that accumulate on the canopy may be harmful for agricultural workers.

A2.6 Economic control model for the Algarve

A spreadsheet model was developed in conjunction with the University of Algarve and the Algarve Regional Department of Agriculture (Mumford & Larcher-Carvalho, 2001) using Microsoft® Excel to quantify the direct and indirect damage caused by Medfly and the costs/benefits of applying SIT. This forms the basis of three potential scenarios for SIT and sterile Medfly demand. A similar analysis can be made in detail for the Ribatejo & Oeste region in due course. In the meantime, a much simpler analysis is done for that region, with a delay of two years.

The model comprises several input sheets that can be grouped into:

1. **Fruit production**. Data on production area of the main hosts for each of the area scenarios, an estimate of the percentage of crop under high and low intensity regime and an estimate of the average yields in high and low intensity regimes, to calculate the total production.

2. The model distinguishes between **high intensity and low intensity orchards**. The main reason being that the use of control methods is related to the dimensions of the farm and the destination of the production. This variable is going to influence the total residual damage and the costs of pesticide use.

3. **Fruit maturation**. This worksheet uses the percentage of fruit maturing each month to calculate the monthly production per crop.

4. **Pesticides costs**. Calculates the total cost of pesticide per crop and per area scenario. The number of pesticide applications in high and low intensity regimes is entered in this worksheet.

5. **Damage model**. In the damage model the potential and actual damage due to Medfly in high and low intensity regimes are entered. Actual damage is related to the number of pesticide applications.

6. **Losses due to Medfly**. The loss model combines the fruit maturation worksheet and the damage model. Monthly market prices are input to calculate the total value of the production at risk from Medfly every month (potential loss) and the value of production loss due to Medfly damage (residual loss)

7. **SIT costs**. The SIT project components include pre-SIT monitoring, staff training pre-SIT, staff training SIT, feasibility studies, project planning, public information pre-SIT, public information for the pilot project, public information during the SIT project, quality control pre-SIT, fly costs for high intensity releases, fly costs for medium intensity releases, fly costs for low intensity releases, fly releases, release centre fixed costs, release centre variable costs, rearing facility fixed costs, rearing facility variable costs, monitoring costs at high intensity, monitoring at medium intensity, monitoring at low intensity and administration costs.

8. **Benefit/cost analysis**. These worksheets compare all the costs of the SIT programme and all the benefits for the different scenarios. The benefits include all the costs caused to the industry by Medfly: control costs relative to current control, the residual losses that occur when pesticides are applied and the losses in backyards. It also includes indirect losses due to secondary pest outbreaks, environmental damage and human health problems. The key outputs of the benefit/cost analysis are 10 and 20 year net present values (NPV) calculation of the stream of net benefits given in the NPV worksheet.

The assumptions were defined after using data from a variety of sources. A literature review of the main publications on Medfly in the Algarve region was carried out. The results of unstructured interviews with several stakeholders were also used. A first meeting was held with the Algarve-Med Team to discuss the structure of the model and to collect statistical data. After this meeting, 100 farmers were interviewed. Finally a second meeting with the Algarve-Med team was held where agreement was reached on all the assumptions in the model.

A2.6.1 Area scenarios

The first scenario considered includes the whole of the Algarve. This scenario was considered a viable option from the technical point of view because this region has some level of isolation. However, the distribution of fruit production indicated that production was concentrated in the areas of Silves and Tavira and this distribution determines the more cost-effective scenarios for SIT use.

Several maps of fruit production were drawn, including a map of production by concelhos, production by freguesias and maps of concentration of fruit production (production/area of freguesia). The maps use the production areas from the agriculture statistical data collected by the National Institute of Statistics in 1999. A map of land use (Corine Land Cover) was reclassified according to host concentration. The overlay of the land use map and the production maps allowed us to (1) classify the Algarve according to the density of hosts, (2) select contiguous freguesias with high, medium and low host density and (3) calculate total area to be treated in each freguesia. It has to be noted however that this method is only approximate and that more precise estimates of the exact treatment areas would have to be done using satellite imagery.

This analysis has led to the definition of four scenarios:

1. The Silves scenario, which includes 7 freguesias and occupies 541 km^2. In this scenario all the area is considered as high host concentration.
2. The Tavira scenario, which includes 10 freguesias and occupies 424 km^2 was also considered a high host concentration area.
3. The Coast scenario includes 38 freguesias and 1860 km^2. This scenario includes the Silves and Tavira scenarios (high host concentration area) as well as a surrounding area with medium host concentration.
4. The Algarve scenario which includes the two high concentration areas, the medium concentration area and finally a larger low concentration area occupying a total of 3144 km^2. The whole of the Algarve comprises 83 freguesias

Note that it is important to define areas according to host concentration because the intensity of the control measures will be different. By defining these scenarios we were aiming at investigating the minimum and maximum areas where SIT would be viable.

A2.6.2.Hosts selected for the analysis

Based on the initial considerations and discussions with the Algarve-Med Team, the following hosts and areas of production were selected for the analysis.

Table A2.2. Area of Medfly hosts for each scenario (ha) (values are rounded)

Hosts/Scenarios	Algarve	Silves	Tavira	Coast
Orange	10 880	4 301	3 226	9 722
Other citrus	4 020	2 566	759	3 829
Apricot	158	13	63	120
Peaches	474	79	99	316
Figs	2 783	364	387	2 013
Pear	97	7	19	52
Plum	101	25	20	71
Apple	27	1	1	6
Exotic	192	102	1	179
Host area (ha)	18 732	7 458	4 575	16 308

A2.6.3. General suppression plan

It was considered that two years of monitoring and preparation would be required to gather data on Medfly populations and host distribution and abundance in the different area scenarios. In year 3 a pilot project would be run to evaluate the viability of SIT.

The density of releases would vary according to host concentration. In high concentration areas the release density was set at 1000 flies per ha, in medium concentration areas at 500 and in low concentration are at 200 flies per ha. Therefore in the Silves and Tavira scenarios releases would be done at high density, in the coast releases would be at high density in Silves and Tavira and medium density in the remaining area. The same principle is applied for the Algarve as a whole. The frequency of fly release was determined by the dynamics of the wild population. The populations are very low during at least three months of the year, therefore the number of weeks for release could be limited to 40. If this provided adequate suppression then costs would be lower than if a full 52 week release programme was used. A suppression scheme would have an associated programme of orchard hygiene in the winter which would reduce the need for other control during those months.

A2.7 Costs due to Medfly damage

The costs presented in Table A2.3. are derived from the pesticide worksheet in the benefit/cost model. The total annual cost of pesticide application in the Algarve amounts to almost US$2.6 million per year.

However, it has to be noted that the control costs for Medfly may change over the next 20 years as there is a trend to try and replace these older products with more environmentally friendly ones. It is also likely that some of these older and cheaper products, such as the organophosphates, will be withdrawn from the market. This is mainly due to pressure from consumers and importing countries to reduce pesticide use in food production. However, these alternatives are more expensive and appear to be less effective.

Table A2.3. Current total pesticide expenditure annually estimated in the four areas

	Algarve	Silves	Tavira	Coast
Cost of pesticide application (US$)	2 635 947	1 132 576	728 612	2 366 460

Residual losses are losses that are still incurred even though pesticides are applied. A subjective appreciation estimated the residual losses taking into account the number of pesticide treatments in the crop and the time of the year. Residual losses are estimated at US$3.8 million per year in the Algarve, US$2.9 million in the Coast, US$1.1 million in Silves,US$0.8 million in Tavira. These losses are included as SIT benefits because control achieved with this technology can be far higher not only due to the technology itself but also due to the higher efficiency of a centrally organized programme.

There was general consensus amongst the main stakeholders that the environmental and health impacts of pesticide use in the Algarve were extremely high. The same is suggested in a literature review. Therefore environmental and health costs were set at US$2 environmental and health loss per US$1 spent on pesticide. This is based on a study by Pimentel *et al.* (1993) in which a value of 2:1 was used for all American agriculture. Because the Algarve is an area with considerable tourism and there is frequent over-use of pesticides, it was believed that

Pimentel's value is probably an underestimation. However, because the model was highly sensitive to this parameter we represented it by means of a probability distribution around Pimentel's value but the possibility of quite higher values is, although much lower, still not zero.

Because there is a strong consensus that secondary pest problems[22] are one of the most important side effects of pesticide use in orchards these indirect losses were included on top of the environmental costs. The losses to secondary pests in citrus were estimated by experts at 3 percent. However, there is a high degree of uncertainty associated with this variable therefore a uniform distribution was also associated with it.

Other indirect impacts considered were the losses due to Medfly in backyard gardens. In backyards usually no pesticides are applied and there is a high diversity of hosts giving ideal conditions for Medfly, therefore the expected damages are very high. Although this production is for home consumption a market price was attributed to it in order to quantify this loss.

Another indirect benefit attributed to SIT was IPM subsidies. By eliminating the need to apply pesticides for Medfly control, SIT makes it easier for farmers to apply for IPM status and to receive the associated subsidy. The payment model is related to the size of the area and the number of applications. In the analysis an average value of US$220/ha was used and it was assumed that every year 2 percent of the host area except figs would apply for the subsidies.

The distribution range for the total indirect losses in the Algarve is shown in Figure A2.4

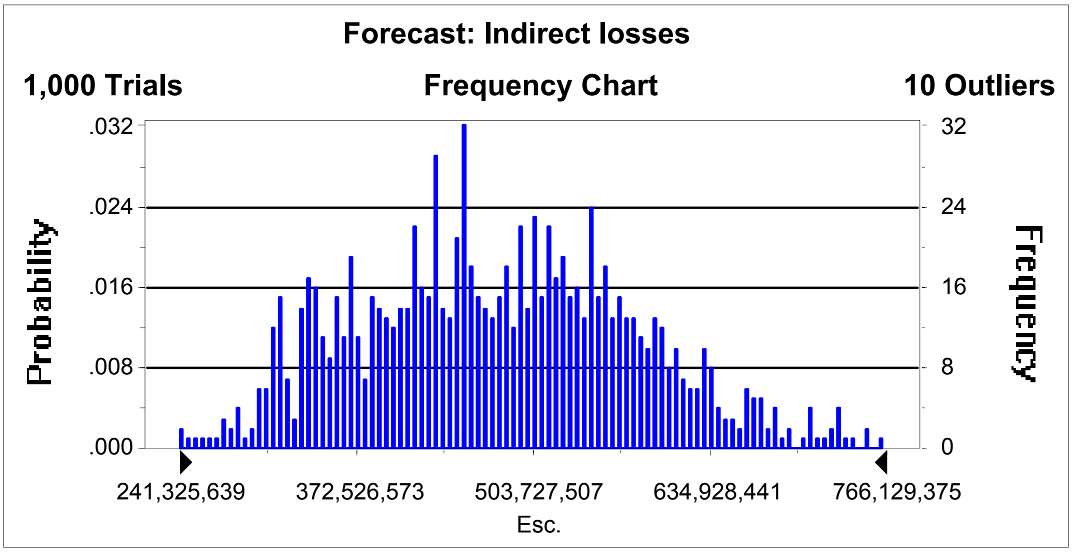

FIG. A2.4. Distribution range of indirect losses in the Algarve (approximately 200 Esc per US$).

[22] Secondary pest outbreaks occur because pesticides cause the destruction of natural enemies that would otherwise maintain the secondary populations under control.

A2.8 Sterile Medfly requirements for SIT

The requirement for sterile male Medflies at release point has been determined based on the type of hosts in each area, as indicated above. A total of 246 million flying sterile male Medflies would be needed each week for 40 weeks for the Algarve scenario, 170 million per week for the Coast scenario, 65 million for the Silves scenario and 52 million for the Tavira scenario. This analysis is based on a 40 week release programme, but if releases were made for 52 weeks per year (as some in the region expect) then the requirements for sterile male flies would be 30% greater.

The costs of producing the flies are very important to the benefit/cost analysis, as they are one of the two main costs of the SIT programme (the other important one being fly releases). It is assumed that the flies would cost US$475 delivered and ready for release in the field. If flies are less expensive then it would be economic to treat larger areas, and the minimum area would be smaller.

The analysis (Mumford and Larcher-Carvalho*,* 2001) suggests that it is not economically viable to run a programme in the whole of the Algarve, as all the economic indices are negative. The costs of such a programme would far outweigh the benefits. This result was certainly expected as this scenario includes an extensive area of 3144 km^2 where the concentration of fruit production is low and where benefits would be very low. Although the intensity of control measures is reduced in low concentration areas, the costs incurred are still very high due to the size of the area to be covered. The highest costs in this case are the release costs as it was assumed that these costs are independent of the intensity.

Running an SIT programme only for the Tavira region does not seem to be a viable option either. This suggests that this area is too small to justify the costs of the programme. Silves is viable as an area for control on its own. This is due to the high concentration of the production. The Coast scenario is also viable. However, the analysis of the probability distribution shows that, under the uncertainty that was defined for the variables, the probability of obtaining a positive return after 10 years is higher for the Silves SIT option than for the Coast SIT option.

In the Oeste region approximately 105 million sterile Medfly males would be needed per week, for about 36 weeks and in Ribatejo 260 million per week for 36 weeks per year. Detailed analysis may show that the larger Ribatejo area has orchards that are too dispersed to be economic, given the large non-commercial area that may need to be treated. These areas may come in later after success was demonstrated in the Algarve.

A2.9 Conclusions

A probability analysis on the number of sterile male Medflies likely to be demanded weekly over a period of seven years for the whole of Portugal was performed. This analysis was conducted using Crystal Ball™ software on a spreadsheet in which probabilities for the uptake of SIT in each region in each year are specified. Table A2.4. indicates the probability weights for each region by year used in the Crystal Ball™ analysis.

Table A2.4. Probability tables on estimated sterile Medfly numbers (millions of males per week) and demand (by year and location)

	Silves		Tavira		Coast		Oeste		Ribatejo	
	Millions	**Prob**	**Millions**	**Prob**	**Millions**	**Prob**	**Millions**	**Prob**	**Millions**	**Prob**
2003	0.000	0.300	0.000	1.000	0.000	1.000	0.000	1.000	0.000	1.000
	65.000	0.700	52.000	0.000	53.000	0.000	105.000	0.000	260.000	0.000
2004	0.000	0.250	0.000	0.400	0.000	1.000	0.000	1.000	0.000	1.000
	65.000	0.750	52.000	0.600	53.000	0.000	105.000	0.000	260.000	0.000
2005	0.000	0.200	0.000	0.325	0.000	0.800	0.000	1.000	0.000	0.800
	65.000	0.800	52.000	0.675	53.000	0.200	105.000	0.000	260.000	0.200
2006	0.000	0.150	0.000	0.250	0.000	0.700	0.000	1.000	0.000	0.700
	65.000	0.850	52.000	0.750	53.000	0.300	105.000	0.000	260.000	0.300
2007	0.000	0.100	0.000	0.175	0.000	0.600	0.000	0.900	0.000	0.600
	65.000	0.900	52.000	0.825	53.000	0.400	105.000	0.100	260.000	0.400
2008	0.000	0.050	0.000	0.100	0.000	0.500	0.000	0.700	0.000	0.500
	65.000	0.950	52.000	0.900	53.000	0.500	105.000	0.300	260.000	0.500
Start	2003		2004		2005		2007		2005	
Start prb	0.70		0.60		0.20		0.10		0.20	
Final prb	0.95		0.90		0.50		0.30		0.50	
Flies (Mns)	65		52		53		105		260	

The assumptions and analyses for Portugal suggest the most likely uptake as indicated in Table A2.5. Figures in italics indicate lower probability of uptake, those in bold indicate higher probability of uptake**.**

Each year has a probability for no flies and for a full uptake for the region. The year uptake may start is indicated below the probabilities, and values are given for the initial and final probability estimates for uptake in each location, with a simple linear progression from the initial year to the final year. The flexibility of this model allows other uptake estimate scenarios to be tested if needed.

The probability-weighted number of sterile Medfly per week (based on demand and probabilities from Table A2.4) for each area is shown in Table A2.6.

Table A2.5. Numbers of flies that would be required in each region if SIT is implemented

Year (with immediate uptake)	**year 1**	**Year 2**	**year 3**	**year 4**	**year 5**	**year 6**	**year 7**
Million sterile male Medfly for release per week (for X weeks/year)							
Silves (7600 ha commercial host)		**65** (40)	**65** (40)	**65** (40)	**65** (40)	**65** (40)	**65** (40)
Tavira (4700 ha commercial host)			**52** (40)	**52** (40)	**52** (40)	**52** (40)	**52** (40)
Other Algarve Coast (5000 ha orchards)				*53 (40)*	*53 (40)*	*53 (40)*	*53 (40)*
Oeste (Alcobaca 25 000 ha orchards, mostly apples and pears) 110 000 ha high concentration fly release; 103 000 ha low concentration						*105 (36)*	*105 (36)*
Ribatejo (SE of Tagus 75 000 ha orchards) 320 000 ha high concentration fly release; 90 000 ha low concentration				*260 (36)*	*260 (36)*	**260** (36)	**260** (36)
Total weekly demand million Medfly (weeks per year)		**65** (40)	**117** (40)	**117**-*430* (36) **117**-*170* (4)	**117**-430 (36) **117**-*170* (4)	**377**-53*5* (36) **117**-*170* (4)	**377**-535 (36) **117**-*170* (4)
Total annual demand – based on areas with higher probability of uptake only		**2 600 million**	**4 680 million**	**4 680 million**	**4 680 million**	**14 040 million**	**14 040 million**
Total annual demand – based on areas of both higher and lower probability of uptake		**2 600 million**	**4 680 million**	**16 160 million**	**16 160 million**	**19 940 million**	**19 940 million**

*Figures in italics above indicate lower probability of uptake, those in bold indicate higher probability of uptake***.** *(Number in parenthesis is the number of weeks in each year that sterile Medfly would be released, due to the seasonal survival.)*

Table A2.6. Numbers of flies that would be required in each region based on expected probability of SIT being implemented (see Tables A2.4 and A2.5)

Year (with immediate uptake)	**year 1**	**Year 2**	**Year 3**	**year 4**	**year 5**	**year 6**	**year 7**
Million sterile male Medfly for release per week (for X weeks/year)							
Silves (7600 ha commercial host)		**45.5** (40)	**46** (40)	**52** (40)	**55** (40)	**59** (40)	**62** (40)
Tavira (4700 ha commercial host)			**31** (40)	**35** (40)	**39** (40)	**43** (40)	**47** (40)
Other Algarve Coast (5000 ha orchards)				*11 (40)*	*16 (40)*	*21 (40)*	*27 (40)*
Oeste (Alcobaca 25 000 ha orchards, mostly apples and pears) 110 000 ha high concentration fly release; 103 000 ha low concentration						*11 (36)*	*32 (36)*
Ribatejo (SE of Tagus 75 000 ha orchards) 320 000 ha high concentration fly release; 90 000 ha low concentration				*52 (36)*	*78 (36)*	**104** (36)	**130** (36)
Total expected weekly demand million Medfly (weeks per year)		**46** (40)	**77** (40)	**150** (36)	**188** (36)	**238** (36)	**298** (36)
				98 (4)	**110** (4)	**123** (4)	**136** (4)
Total annual demand – based on expected probability of uptake calculated from Table A2.4.		**1 638 million**	**2 772 million**	**5 792 million**	**7 208 million**	**9 060 million**	**11 272 million**

A2.10 References

References in individual Annexes may have “a”, “b” etc. following the publication date, this refers to the way they appear in Section 9.1 Bibliography where all references are listed.

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Annex 3
On-site study of the potential market for sterile Mediterranean Fruit Fly in Morocco

Citrus production has remained stable in Morocco since 2000. Areas and production have not increased at the expected rate of growth: the average area from 2002 to 2005 remained at slightly less than 80,000 mt and production at around 1.2 milllion (USDA/FAS, 2005). The area of apples, the second most important commercial host, has decreased slightly to 26,700 ha, but production increased to 372,500 mt (Oukabli, 2004). There was a small decrease in the areas and production of apricots while plum areas and production increased.

Morocco has taken several steps towards the implementation of an SIT programme: A Technical Cooperation Project with the IAEA started in 2005 to assess the feasibility of SIT in one selected area and to build capacity for SIT application. It involves the Plant Protection Directorate (*Direction de la protection des végétaux, des controles techniques et de la repression des fraudes*, DPVCTRF) from the Ministry of Agriculture. An SIT seminar was organized by Citrus growers, CLAM and the Cleanfruit project in Agadir, to clarify the current situation (Cleanfruit, 2006a). Later, CLAM also helped organise a visit to the SIT programme in Valencia for a Moroccan delegation. Morocco is now planning a pilot SIT project in Souss (South), under leadership of the DPVCTRF, covering 3000 ha, mostly of citrus. There have been some steps taken to tender for a supply of 6 million sterile Medflies a week, but no contract has been issued at the time of this revision.

The recommendations below regarding wild hosts and release levels remain valid, and will hopefully be useful to the newly initiated programme.

A3.1 Introduction

The Medfly is undoubtedly a major pest that causes widespread damage on citrus, stone fruit and pome fruit in Morocco. It is a key factor in the determination of insecticide use, resulting in secondary pest development as a result of sprays killing natural enemies. According to the International Atomic Energy Agency (Mumford *et al.*, 1995) projections, the annual economic losses caused by Medfly in Morocco are an estimated US$53.2 million (averaged over the period 1990-1999). Those losses include Medfly damage as well as pesticide control costs. They do not include potential loss of markets arising from failure to compete on quality in new and existing fruit markets.

Despite good control using bait sprays, changes in consumer buying habits, public awareness and the enforcement of new international phytosanitary agreements have all caused importers to demand higher quality standards than in the past. New production strategies must meet these standards by supplying the global produce market with fruits that are within regulated limits of pesticide residues (maximal residue limits or MRLs). The most important fruit market for Morocco, the European Union, has lowered the MRLs for registered pesticides and eliminated other pesticide options recently (Cleanfruit 2006b and 2006c). Some markets now prefer organically produced fruits. These changes are extremely important for the Moroccan economy, because of the importance of citrus exports, and the current control regimes may lead to market loss due to residues. Moroccan producers should be increasingly receptive to SIT-based Medfly control strategies in order to meet the new quality demands of the export fruit market. Both the European Union and CLAM (Mediterranean Citrus Liaison Committee) have expressed their support for a rapid development of the SIT for use against Medfly in the Mediterranean Basin (FAO/IAEA 2000a).

Within the domestic market in Morocco, results of this study suggest that SIT can increase fruit affordability and consequently allow low-income households to increase their fruit purchasing because of lower prices[21]. In parallel, exports may obtain a higher value and retain or increase market share because of quality improvement and better compliance with market regulations. Previously, the potential use of SIT across the Maghreb was evaluated and considered favourably in terms of the likely reduction in fruit damage and pesticide applications (Mumford *et al*. 1995).

The present study focuses on the Moroccan case. The main objective of the report is to assess the demand for sterile Medflies over the next 10 years along with the economic benefits of Medfly SIT management. Issues of location and potential volume of sterile Medfly are addressed in the implementation of area-wide insect control programmes for two options. The first option concerns fly suppression from commercial hosts in areas that cover 1372 km^2. Some surrounding boundary areas would also be covered in this approach, to ensure good coverage and reduce immigration of Medflies from wild hosts. The second option considers a possible SIT eradication programme in which all wild host areas are also included in the Medfly control strategy. The total area that would be involved in such a programme amounts to 10 878 km^2, including wild Argan forest, *Opuntia* and other shrub areas that are known as Medfly shelters.

The report is organized in two further sections. Section A3.2 presents the extent of the Medfly problem in Morocco by indicating the economic importance of the Medfly commercial hosts and current control costs. Section A3.3 analyses first the sterile male insect requirements for the main fruit production zones. Secondly, a cost benefit analysis is described which covers national SIT strategies using the available data. There are then some concluding remarks on the overall viability of SIT in Morocco.

A3.2 The Medfly problem in Morocco

There are as many as 350 plant species that can be damaged by the Medfly, many of which occur in Morocco. Two types of ecological zones are seriously affected in Morocco. The first includes areas with a wide range of commercial fruit production including citrus, apricots, apple, peaches and nectarines, pears, plums, figs and cherries. The second is composed of widespread areas with wild hosts for the Medfly, mainly Argan (*Argania spinosa*), *Opuntia* and some other natural forest plants and shrubs (Mazih 1992; FAO/IAEA 1992).

Argan is an indigenous fruit-producing tree that produces most of its fruits from March to July, but can bear fruit all year round. Each fruit can feed multiple Medfly larvae. *Opuntia* is grown as field fences almost everywhere. The fruiting season of this prickly pear cactus stretches from June to October, thus ensuring the subsistence of Medflies during the summer, fall and winter. Together, Argan and *Opuntia* constitute the major non-commercial wild host species of the Medfly, threatening infestations to other areas throughout the year.

In Morocco, most commercial areas are adjacent to or within wild host zones. The zone of Agadir, on the southern coast, is particularly known as an area of high Medfly infestation.

[21] In Morocco, fruit are considered as normal to luxury commodities with an expenditure elasticity of 1.2 (Douidich 1995).

Conditions in Agadir are optimal for Medfly reproduction and development due not only to the favourable weather conditions but also to the presence of both wild (mostly Argan) and commercial (citrus) hosts.

A3.2.1 Economic importance of the commercial hosts

Currently, the main commercial host species cover a total area of 137 200 hectares and produce more than 1883 thousand mt of fruit (Table A3.1). Fruit production, including citrus, is of great economic importance, the fruit production sector produces an aggregate market value that averages US$600 million annually and it generates more than 68 million man-days of work per year (ADAM, 2001).

Citrus is the most important fruit crop, occupying more than 50 percent of the total Moroccan commercial fruit production area. The area devoted to citrus has increased from 70 000 ha in 1990 to 80 000 ha in 2000, at an average annual rate of 1.3 percent. Between 1997 and 2000, the average annual citrus production has been estimated at 1.3 million mt, of which oranges accounted for 35 percent, clementines 28 percent, navel oranges 20 percent and others 17 percent. Citrus fruits are Morocco’s principal export crop and they generate about US$265 million annually in earnings. The national market is supplied with citrus all year round due to the existence of varieties that have different harvest seasons. During the last two years, the domestic market has absorbed 58 percent of the total citrus crop while the rest (42 percent) has been exported.

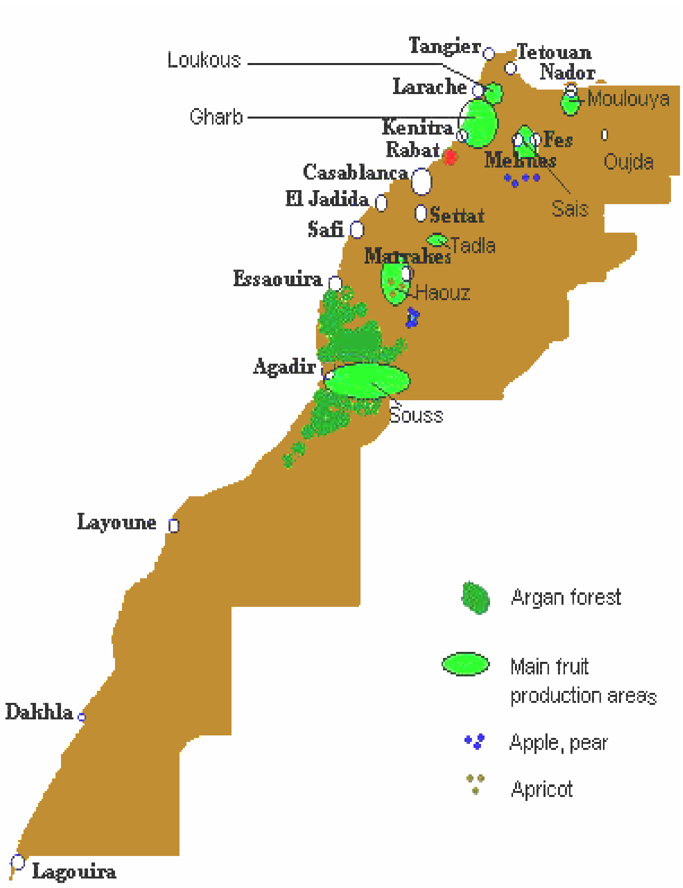

FIG. A3.1. Key fruit production areas of Morocco.

Morocco's citrus production areas are situated in various plains where ecological conditions are most appropriate; of these, the most important are:

- Souss and Haouz (in the south), with 36 percent and 10 percent of the total citrus area respectively;
- Gharb and Loukkous (in the north) with 22 percent and 3 percent respectively;
- Moulouya (in the northeast) with 15 percent;
- Tadla (in the centre) with 5 percent;
- Various other isolated sites with 9 percent.

The other important commercial hosts for Medfly in Morocco are several species of pome and stone fruits. They occupy more than 61 000 hectares and are mainly grown around the Mid-Atlas mountain chain. Apples are the most important crop in this group and their production covers the largest area, more than 28 000 ha. The next most important crop is apricots, with 14 000 ha. The remaining crops occupy relatively small areas.

The main wild hosts are of lesser economic value. However, these host plants allow the Medfly to complete its biological reproductive cycle regardless of the control strategies adopted in the commercial zones. To give an indication of the size of some of the wild host regions, it can be noted that there are about 700 000 to 800 000 hectares of Argan trees, mainly in the region of Agadir.

Table A3.1. Average area, production and yield of the main commercial Medfly hosts (1997-2000)
Source: DPVCTRF (2001)

Crop	Area (1 000 ha)	Production (1 000 mt)	Yield (mt/ha)
Citrus	76.0	1 300.0	17.1
Apples	28.0	292.0	10.4
Pears	4.0	50.0	12.5
Plums	3.0	31.0	10.3
Peaches and nectarines	4.1	45.3	11.0
Apricots	14.0	106.0	7.6
Quince	6.8	51.0	7.5
Others	1.3	7.2	5.5
Total	137.2	1 882.5	-

A3.2.2 Medfly damage estimation

The principal damage caused by the Medfly occurs at the production stage when infested fruit must be discarded because of inadequate protection by chemical sprays. According to interviews, these losses can affect from 20 to 30 percent of the citrus production. Lower prices and the loss of export opportunities due to Medfly infestations result in additional economic losses for the producers. For their part, the consumers suffer the effects of pesticide control measures both on the environment and on human health, as well as having to pay relatively high prices for fruits. Another problem associated with the use of chemical pesticides is the outbreak of secondary pest infestations (such as scales and aphids) due to the destruction of their natural predators. This is also a common problem in neighbouring countries, such as Portugal (Mumford and Larcher-Carvalho, 2001b).

Table A3.2 shows the estimated total damage caused by the Medfly to its principal commercial hosts in Morocco. The data are based on Driouchi (1990) but have been corrected to take into account inflation rates and exchange rate variations between 1990 and 2000. The coefficient of loss adjustment assumes a linear growth rate for production between 1990 and 2000, varying from 1 percent for plums to 4 percent for apricots (it is 2 percent for citrus). This finding suggests that changes in relative costs for Medfly control strategies have not been significant over this period. Professionals in the field who were interviewed support this. Nevertheless, it is to be noted that this data adjustment is only approximate and that more accurate results would require additional information that would need to be gathered through a broad survey programme.

The physical losses caused by the Medfly to the main commercial crops in Morocco are estimated to reach 170.3 thousand mt. This amount represents 9 percent of production. The total monetary value of the damage, assessed at the production, marketing, and export stages, is about US$51.4 million. Citrus accounts for more than 45 percent of the total monetary loss. Stone fruit are the second most affected fruit group, with almost 51 thousand mt of losses, accounting for 34 percent of the total monetary loss. Stone fruits are heavily affected because the Medfly usually attacks the first fruits to ripen after low temperature seasons, such as apricots. In fact, the harvesting periods for stone fruit and for the late varieties of citrus (Maroc Late) coincide with the peak of Medfly activity in Morocco (June and July).

Table A3.2. Estimated annual losses and control costs attributed to Medfly infestation on its main commercial hosts in Morocco (2000)

Crop	Damage level		Pest control	Total
	Losses (1000 mt)	Value (US$ million)	(US$ million)	(US$ million)
Citrus	86.4	23.21	7.16	30.37
Apples	27.6	7.36	0.67	8.03
Pears	5.2	1.38	0.13	1.51
Apricots	33.2	11.07	0.84	11.91
Peaches and nectarine	10.3	5.04	0.12	5.16
Plums	4.5	1.51	0.28	1.79
Quince	2.0	1.06	0.10	1.16
Others	1.1	0.80	0.10	0.90
Total	170.3	51.43	9.40	60.83

Table A3.3 shows the proportional losses anticipated in each of the four main fruit producing regions of Morocco. Losses are greatest in the south, and citrus accounts for most of the control cost, but less of the overall loss.

A3.2.3 The cost of chemical controls

The most common technique in Morocco for controlling Medfly damage on commercial crops, both for export and local markets, is to use bait sprays. The treatment consists of applying a mixture of an insecticide and a protein that attracts both male and female Medflies. The main active ingredients that are officially authorized in Morocco for use in sprays are trichlorfon, malathion and dimethoate (DPVCTRF, 1998; Boukhsim, 2001). All three of these products are included in a list of products to be phased out by suppliers to Marks & Spencer, a leading quality-end supermarket in the United Kingdom (Marks & Spencer communication, 2002). In the intensive farming units, pesticide control starts with trapping. The trigger threshold for insecticide treatment varies from 3 to 5 flies per trap (Mazih, 1992; Ouahid, 1997; Dbira Tlemçani, 1999). Vincenot (1993) and Papacek (1997), cited by Jahaz (1999), suggest that the threshold should be set at the 1 percent fruit damage level. Pesticide may then be applied to the entire orchard or localized. The latter is most frequently performed by only treating every second or third row in order to reduce costs. Both trapping and damage thresholds may allow Medfly levels to rise too high before control can be effectively applied, which would be avoided with area-wide SIT.

The cost of pesticide applications varies among the various Moroccan production regions as well as between high and low input operations. On average, three to four applications are usually needed on citrus crops each year; however, this number rises to ten applications in the region of Agadir (South) and decreases to two or three in Gharb (North) and in Berkane (Northeast). Using data from Driouchi (1990) and information supplied by the extension service, it is estimated that the total cost for the chemical control of the Medfly in Morocco was approximately US$9.4 million in 2000 (Table A3.3). Citrus fields account for 76 percent of this cost. This is because they are usually treated more often than other crops, such as peaches and nectarines, which are normally only treated once or twice each year in the region of Sais (Benjelloun, 1994; personal interview).

Table A3.3. Annual losses and control costs estimated due to Medfly in Morocco by region and by crop (2000)

Region	Loss ($mn)	Control cost ($mn)	Proportional production by area Citrus	Other	Total	
Northeast	4.88	1.18	0.15	0.05	0.11	
North	8.76	1.99	0.24	0.11	0.18	
Central	17.18	2.09	0.14	0.50	0.30	
South	20.60	4.14	0.47	0.34	0.41	
Overall	51.42	9.40	1.00	1.00	1.00	
			Citrus	Other	Total	
Loss by crop			23.21	28.21	51.42	$mn/year
Control by crop			7.16	2.24	9.40	$mn/year

A3.2.4 The total cost of Medfly control

The total economic cost of the Medfly in Morocco can be estimated by aggregating the value of the actual damage done by the pest and the costs of the attempts to suppress it. Table A3.2 shows that the financial losses and costs caused by the pest reaches just over US$60 million per year. This amount is US$7 million higher than the projected cost estimated by Mumford *et al*. (1995) primarily because of the increases in the areas devoted to stone and pome fruit production between 1990 and 2000. Expressed per surface unit, the average total cost amounts to US$443 per hectare, with costs higher in the region of Agadir (South) and lower in the region of Gharb (North). Between the two components of total cost, the proportion due to direct Medfly damage accounts for 85 percent of the total cost.

Besides the purely financial aspects of the Medfly damage, there are other problems related to pest control measures that are associated with environmental and human health issues. In fact, massive applications of pesticides inevitably lead to serious environmental concerns, regardless of the precautions taken with their application. Unfortunately, there has been little research done in Morocco on the issue of repeated pesticide use or its consequences. However, under pressure from the major importers of citrus (EU, USA, Canada, Japan, Russia) Moroccan producers must now comply with demands for drastic restrictions on chemical residues. For example, citrus fruit sprayed with dimethoate must contain less than 1 ppm of active ingredient if it is exported to any country of the EU (EACCE, 2001). Such restrictions place more incentives on the producers to adopt better pest control strategies. Consequently, additional investments are also considered for control of infestation by using commodity treatments such as the cold treatment of citrus shipments22.

Also, since the Medfly is under strict quarantine in the USA, Moroccan agricultural exporters are very aware of the problems that the Medfly presents for trade with this country. This concern has been heightened by rejections of Spanish citrus in the USA during the past year due to Medfly infestation. In this respect, the Moroccan Ministry of Agriculture has implemented a cooperation project to convince American tomato importers that tomato varieties grown in Morocco are resistant to the Medfly (SASMA, 1995). Thus, even if a crop is known as a secondary host of Ceratitis capitata, foreign commercial opportunities may be lost by producers because of the threat attributed to Medfly for importing countries that wish to maintain their Medfly-free status.

All these additional costs should be included as indirect effects of Medfly suppression costs, if such data are available. That means that for environmental and health issues, those costs may be increased by a percentage factor to take into account the foregone social benefits. Pimentel *et al*. (1993) (cited by Mumford and Larcher-Carvalho (2001b)) suggest that a factor of 2 to 1 may be used to include the additional costs generated by Medfly chemical control efforts[23]. This cost would seem to be quite high in the Moroccan context, where market proxy values for environmental loss are likely to be lower than in the USA. Mumford *et al*. (1995) proposed a value that requires the cost of the pesticide to be matched as an environmental cost (that is, \$1 additional cost per \$1 of pesticide expenditure). Such costs should be taken into account in cost/benefit analyses.

A3.3 Economic approach of the SIT programmes

Among producers and stakeholders, the main deterrent to using the SIT against Medfly is lack of confidence that this technique will be effective because of the presence of natural host plants all the year around. Discussions with professionals and officials revealed that the majority of the producers need to be introduced to the technique and convinced of SIT efficiency. Thus, technical assistance aimed at demonstration of the effectiveness of the technique should be involved in all regional programmes aimed at using Medfly sterile males. In addition to proving technical performance, presenting the potential outcome of SIT in economic terms will be a useful tool for its acceptance among producers.

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[22] The cold treatment consists of a transportation of the fruit in containers that are kept at or below an indicated temperature for a specified length of time (based on the results of research). Residual Medfly eggs and larvae do not support this lower level of temperature. This treatment may be applied during transport, but if the temperature rises above the indicated temperature at any time, the shipment is rejected.

[23] This means that one would apply a cost of US\$2 for the environmental and health loss per US\$1 spent on pesticides, excluding labour and equipment.

A more detailed economic analysis will take into account first, the cost of the sterile Medfly and other project requirements and, secondly, the cost/benefit of SIT for suppression and SIT eradication programmes. Technical and economic data are available from government statistics (especially the Ministry of Agriculture) and various publications. Both suppression and eradication are assumed to require a preliminary phase. During that period, intensive monitoring would be undertaken in the control zones and detailed plans for the field campaign would be developed in parallel with activities to consult with and educate stakeholders of the SIT programmes. Thus, centrally managed insect control programmes must be set up in concert with all fruit sector operators and Ministry of Agriculture officials and technicians.

A3.3.1 Medfly host area

Either suppression or eradication programmes could be conducted in a phased operation in the four geographical zones that are the main fruit production areas (Table A3.4). Zone A (South) is composed of Souss Massa (around Agadir city) and Haouz (Marrakech) and consists of plains producing mainly citrus over an area of 360 km^2 (36 030 ha). That zone also includes an estimated wild host area of 8000 km^2 where Argan forest accounts for 87 percent of the vegetation. Zone B (Central) covers almost 909 km^2 with mainly stone and pome fruit as commercial hosts (304 km^2) grown in Tadla (Beni Mellal), Mid Atlas region (Khenifra, Azrou, Midelt, Ifrane, Imouzzer) and the Sais plain (Meknès, Fès, Sefrou). Zone C (North) includes Gharb (Kénitra) and Loukkous (Larache) areas totaling up to nearly 754 km^2 of Medfly susceptible hosts. Zone D (Northeastern) is mainly citrus-oriented for commercial hosts (114 km^2) and covers an area of almost 645 km^2, of which Moulouya plain (Berkane) is the major component. Besides Argan forest, the other principal wild host is *Opuntia*, as well as various shrubs and bushes. The projected area for wild hosts includes all these species.

Table A3.4. Areas of Medfly hosts in Morocco

Areas	**Zone**	**Hectares**				
		Citrus	Other	Commercial	Wild	Total
Northeast	D	11 400	3086	14 486	50 000	64 486
North	C	18 630	6752	25 382	50 000	75 382
Central	B	10 450	30 442	40 892	50 000	90 892
South	A	36 030	21 020	57 050	800 000	857 050
	Total	76 510	61 300	137 810	950 000	1 087 810

In order to demonstrate SIT efficiency to producers and officials, such a programme may start by concentrating efforts on smaller areas. Zone D (Berkane region) is well suited for a pilot project where SIT could be implemented over the short term. The geography and ecology of that region make it a good prospect for an SIT area-wide programme. Berkane benefits from the natural barrier of the Mediterranean Sea on the north and from a relatively barren desert area that separates it from Sais Plain (almost 400 km) on the south. Due to these natural barriers, and according to the opinion of fruit production professionals and entomologists, the experience that would be gained with the Berkane region would facilitate the subsequent extension of the campaign to the next zones (Figure A3.1).

A3.3.2 Sterile Medfly requirements

As proposed above, the use of SIT for suppression or eradication programmes is currently considered as an option for the management of Medfly in Morocco. The requirements for sterile flies are based on the estimated size of commercial and wild susceptible areas in each zone. The density of releases would be linked to the relative concentration of hosts in each area. Mumford and Larcher-Carvalho (2001b) suggest that the density of releases would vary with the host concentration, with 100 000, 50 000 and 20 000 male flies per km^2 and weekly respectively in high, medium and low concentration areas. The intense fruit producing areas of Morocco are likely to have conditions similar to those in the high concentration areas of Portugal, indicating a release rate of 1000 male flies/ha. For the Maghreb region, Mumford *et al*. (1995) proposed an average weekly release density throughout the area of 50 000 male flies per km^2. This analysis is based on a release density of 1000/ha, but if field studies of the actual density of Medfly showed that the lower figure would provide sufficient control, returns would be much greater. However, using lower numbers of sterile flies could increase the risk of control failure, and much greater costs in the long run, especially in the South.

In Morocco, Zone A (Agadir, Marrakech) would require the highest number of Medfly releases because of the presence of wild Argan forest, the major host of Medfly in the country. Therefore, 100 000 male flies per km^2 host area would be required throughout the season if an eradication programme is selected. The remaining zones may apply the same density of sterile flies, but in somewhat shorter periods related to the local ecological characteristics and fly population dynamics.

Table A3.5 SIT male fly release needs in Morocco

SIT Costs						
Flies	$900	per million	imported and delivered, live male flies, including capital costs, production costs, transport and allowing for mortality in shipping			
	To this base cost are added the following costs, depending on the operation					
Other costs suppression	1	x fly cost	includes release, monitoring, publicity and other project costs			
Other costs eradication (first year of eradication in a zone)	1.5	x fly cost	includes release, monitoring, publicity and other project costs - these costs are higher for eradication than suppression			
Ongoing eradication (for later years, after initial eradication)	0.5	x fly cost	includes continued preventative release in areas that might be subject to reinvasion, or cleaning up any outbreaks			
	The number of flies needed is adjusted for areas at the boundaries of the treated area					
Overfly rate suppression	1.5	extras to cover boundary				
Overfly rate eradication	1.2	extras to cover boundary				
	The environmental impacts are estimated by a factor based on pesticide expenditure					
Environmental cost	1	Per $ on pesticides		0.7	chemical proportion	
Discount rate	0.08					
Start-up costs	2	$mn	spread over 5 years in proportion:			
		0.3	0.2	0.1	0.1	0.3

Sterile male flies needed:	1000	per week/ha	40	weeks per year for Central through North/Northeast
			52	weeks per year for South

	Male flies millions/year Continuous suppression	Male flies millions/year Initial eradication
Northeast	**869**	**3095**
North	**1523**	**3618**
Central	**2454**	**4363**
South	**4450**	**53 480**

post eradication assume 20% rate of continued preventative fly release

The 1.5x (eradication) and 1x (suppression) multiplier factor to account for "other costs" as a product of the cost of flies is taken from the recent study of Western Australia (Mumford et al., 2001). The overflying rate (which includes an extra proportion of flies to cover boundary areas outside the control zone) is based on the assumption that smaller fields, with larger spaces between them, require more extra flies to cover the edges of the area treated, as aerial release cannot be totally precise in its coverage. By treating only those areas with hosts, there is more overflying but less total area.

The environmental benefit will, in this case, equal the total cost of control calculated above, assuming environmental damage is valued at $1 for each $1 spent on pesticide, so US$9.4 million per year.

The cost benefit analysis is based on a 10-year model of inputs and outputs. Model inputs are illustrated in Tables A3.5-7. A key feature of this modeling approach is that variable values can be adjusted with new information and the precision of the estimate can be increased as information becomes available. It also allows the sensitivity of values to be tested, which helps to set priorities for what information is needed in greater detail.

The time frame is an important aspect to consider. Longer time frames can show greater potential returns, but the uncertainty over longer-term estimates also increases. Shorter time horizons are, by contrast, more certain. The 10-year horizon used in this case is a compromise that gives sufficient indication of the returns to plan investment without taking undue risks on long-term uncertainty.

A3.3.2.1 SIT suppression programmes

In a SIT suppression programme, pesticide applications would be reduced leaving the job to be mostly done by the sterile male flies. The efforts would be focused on the economic areas where commercial hosts should be protected from Medfly damage. Table A3.6 depicts total flies needed in each zone for a suppression programme running until 2013. Here, Zone A (South) requires a release of 1000 sterile males per hectare per week for 52 weeks of the year. If one assumes an overflying rate for suppression of a factor 1.5 (extra amount to fill in spaces between host areas) then this amounts to a total release of 4450 million flies annually to protect crop areas. It must be noted that the wild host areas are not included in the suppression programme (apart from areas included in the overflying above). Zone B (2454 million flies/year), Zone C (1523 million flies/year) and Zone D (869 million flies/year) are all calculated accordingly.

For the suppression programme, the proposed course of action is to start releasing in Zone D (Northeast) in 2004 and then gradually to extend releases across the other areas so that by 2008 releases would start in Zone A. At full capacity a total annual supply of 9269 million sterile males would be required to suppress Medfly over 137 200 ha of commercial crops.

Note that this scenario for a suppression campaign is analysed as an illustration. Suppression could be carried out in only some of the regions, for example. The rate of adoption could also be changed, to allow for faster or slower take-up of SIT suppression, depending on expectations.

Table A3.6. Estimated costs and benefits for Medfly SIT suppression

Suppression operations										
		2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Northeast			S	S	S	S	S	S	S	S
North					S	S	S	S	S	S
Central						S	S	S	S	S
South							S	S	S	S
	Million flies/yr		869	869	2392	4846	9296	9296	9296	9296
Costs ($ million/yr)										
Northeast			1.564	1.564	1.564	1.564	1.564	1.564	1.564	1.564
North					2.741	2.741	2.741	2.741	2.741	2.741
Central						4.416	4.416	4.416	4.416	4.416
South							8.010	8.010	8.010	8.010
General start-up		0.600	0.400	0.200	0.200	0.600				
	Total	0.600	1.964	1.764	4.506	9.322	16.732	16.732	16.732	16.732
Benefits ($ million/yr)										
Northeast			5.706	5.706	5.706	5.706	5.706	5.706	5.706	5.706
North					10.153	10.153	10.153	10.153	10.153	10.153
Central						18.643	18.643	18.643	18.643	18.643
South							23.498	23.498	23.498	23.498
	Total	0.000	5.706	5.706	15.859	34.502	58.000	58.000	58.000	58.000
Net benefit ($ million/yr)										
Northeast			4.142	4.142	4.142	4.142	4.142	4.142	4.142	4.142
North					7.412	7.412	7.412	7.412	7.412	7.412
Central						14.227	14.227	14.227	14.227	14.227
South							15.488	15.488	15.488	15.488
General		-0.600	-0.400	-0.200	-0.200	-0.600				
	Total	-0.600	3.742	3.942	11.353	25.180	41.268	41.268	41.268	41.268
NPV (10yr)		**$161.10**	**million**			*S indicates Suppression operation in that zone that year*				
IRR (10yr)		**656%**								

Table A3.7. Estimated costs and benefits for Medfly SIT eradication, based on one potential eradication scenario.

Eradication operations	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Northeast		E	x	x	x	x	x	x	x	x	x
North				E	x	x	x	x	x	x	x
Central					E	x	x	x	x	x	x
South						E	x	x	x	x	x
Million flies/yr		3095	619	4237	5706	55695	12911	12911	12911	12911	12911
Costs ($ million/yr)											
Northeast		6.964	1.393	1.393	1.393	1.393	1.393	1.393	1.393	1.393	1.393
North				8.141	1.628	1.628	1.628	1.628	1.628	1.628	1.628
Central					9.816	1.963	1.963	1.963	1.963	1.963	1.963
South						120.330	24.066	24.066	24.066	24.066	24.066
General start-up	0.600	0.400	0.200	0.200	0.600						
Total	0.600	7.364	1.593	9.734	13.437	125.314	29.050	29.050	29.050	29.050	29.050
Benefits ($ million/yr)											
Northeast		5.706	5.706	5.706	5.706	5.706	5.706	5.706	5.706	5.706	5.706
North				10.153	10.153	10.153	10.153	10.153	10.153	10.153	10.153
Central					18.643	18.643	18.643	18.643	18.643	18.643	18.643
South						23.498	23.498	23.498	23.498	23.498	23.498
Total	0.000	5.706	5.706	15.859	34.502	58.000	58.000	58.000	58.000	58.000	58.000
Net benefit ($ million/yr)											
Northeast		-1.258	4.313	4.313	4.313	4.313	4.313	4.313	4.313	4.313	4.313
North				2.012	8.525	8.525	8.525	8.525	8.525	8.525	8.525
Central					8.827	16.680	16.680	16.680	16.680	16.680	16.680
South						-96.832	-0.568	-0.568	-0.568	-0.568	-0.568
General	-0.600	-0.400	-0.200	-0.200	-0.600						
Total	-0.600	-1.658	4.113	6.125	21.065	-67.314	28.950	28.950	28.950	28.950	28.950

NPV (10yr) **$106.48 million**
IRR (10yr) **131%**

E indicates Eradication operation in that zone that year
x indicates ongoing Eradication follow-up operation in that zone that year

A3.3.2.2 SIT eradication programme

Acting on an area-wide basis, an SIT eradication programme would require sufficient numbers of Medfly sterile males to be air dispersed over the targeted area and its adjacent zones. Targeted areas include commercial areas as well as wild reservoirs in each zone. The geographical surface that would be dealt with amounts to 10 878 km2 where wild hosts account for 87 percent.

Table A3.7 shows estimated sterile male flies required for each zone. The density of release is the same that would be used in SIT suppression programmes (but monitoring and subsequent quarantine and certification actions would be more intense). Zone A would require around 1028 million flies per week during 52 weeks. Thus, the annual need amounts to 53 480 million flies. Zone B would need a weekly aerial release of 109 million flies per week during 40 weeks totaling up to 4363 million flies annually. Zone C would require 90 million sterile males each week, which amounts to an annual 40 weeks need of 3618 flies. Zone D, which may play the role of pilot area for an SIT eradication demonstration programme, would need 77 million flies over a period of 40 weeks. Thus, Zone D would require an estimated annual need of 3095 million flies from 2003 onwards.

After the initial eradication effort in each zone it is assumed that as a follow-up there would be a continued need to release about 20 percent of the original number of sterile males flies in a continuous programme of preventative release (in areas prone to high risk of regular reinvasion) or in isolated outbreak areas if they occur. This leaves a long-term demand for just under 13 000 million sterile male Medfly per year across the country as a whole.

This eradication scheme has a very high requirement for flies in the year when the eradication takes place in the South zone. Over 55 000 million flies would be needed in that year, compared to a long-term need for only 13 000 million/year. This will require careful planning to ensure a suitable supply. It would not be appropriate to build a local capacity for 55 billion/year for a single year, so alternative supplies would need to be found.

The eradication in the South zone would account for a very substantial part of the overall cost of eradication. Almost 80 percent of the cumulative cost up to the point eradication is achieved would go on eradication in the South zone. This assumes this eradication can be achieved in one year in that zone. If it were to take two years there would be very significant reductions in the overall profitability of eradication. Careful technical consideration would need to be given to validate the assumption that eradication could be achieved within one year in a zone of 8571 km^2, with around 8000 km^2 of Argan forest and optimal climatic conditions.

Such an SIT campaign may be conducted in zones phased from the North or the South and going forward with strict measures against re-infestation. Again, the analysis presented shows one likely scenario, beginning with the most practical zones in the Northeast and progressing steadily to finally eradicate in the South zone. Alternative strategies could be modeled subsequently, depending on further technical planning for eradication.

A3.3.3 Cost/benefit analysis

Under the prevailing control technologies, producers, consumers and officials have a primary concern about the cost and efficacy of the SIT. For that purpose, a 10-year-based cost/benefit analysis is presented in order to assess on-going costs and benefits of such a programme for the whole country. Thus, the analysis considers the long-term release of sterile insects in substitution of pesticide use. The key outputs of the benefit cost analysis are the 10-years net present values (NPV) and the internal rate of return (IRR) for the whole country.

The cost/benefit analysis is performed using Microsoft® Excel spreadsheets in accordance with the two possible SIT options (suppression and eradication). In both cases, the main objective is to provide guidance concerning the financial returns of the potential SIT programmes. The SIT costs include all the charges: the campaign preparation costs, flies and release costs, and monitoring and subsequent quarantine (for eradication) and publicity. The sterile flies are assumed to be purchased from abroad and there are no specific plans to construct a Medfly factory in Morocco in this analysis. It is assumed that the flies ready for release would cost US$900 per million and the SIT management (trapping, preparation, fly release, administration, etc.) would approximately equal the cost of the flies themselves following an IAEA estimation that has shown the breakdown of SIT costs (Mumford *et al*., 1995) and other recent SIT cost analyses (see Table A3.5). The cost of flies assumes they are bought from a commercial fly supplier and include production, shipping and an allowance for mortality en route. This assumption overcomes the need to plan for capital costs of a local fly production facility and its operation. While costs of shipping and mortality are therefore extra costs, it is likely that a large, international commercially operated facility would be more efficient in production and would reduce local administrative costs, allowing the national programme to concentrate on field operations. These figures give an indication of the likely returns from SIT, and more detailed analyses of the alternatives of rearing or purchasing flies could be compared before proceeding with a programme.

Beyond the cost of the sterile flies and SIT management, other costs would include training and administrative needs that would apply over the two first years (2002 and 2003). We assume that such costs would amount to US$2 million over the first 5 years of either SIT suppression or SIT eradication. As seen in Section A3.2, all current Medfly related costs, including Medfly damage, control cost, environmental and human health costs, subsequently become SIT benefit components. Streams of those benefits would increase progressively from 2003 to 2008 and then stabilize once full-scale suppression or eradication was achieved.

Tables A3.6 and A3.7 show that in both programmes, benefits would outweigh costs. The SIT suppression NPV amounts to US$161 million, while the NPV is evaluated at US$106 million for the SIT eradication programme. Such results are somewhat different from those calculated by IAEA in 1990 with US$202 million and US$178 million respectively for a time horizon of 15 years (Mumford *et al*., 1995). Note that if the eradication in the South zone were to take two years, instead of one, then the costs would increase by an estimated $96 million and the overall NPV for 10 years would fall to only $10.2 million, with an IRR of only 4 percent.

These estimates do not consider benefits from potential market retention or expansion due to reduced pesticide residue pressures from SIT managed fruit. Given the scale of the export fruit industry ($265 mn from citrus alone), even small changes in the total value of the market kept or increased would cover the costs of SIT. For example, the estimated annual cost of SIT suppression for all zones ($16.7 mn/year in Table A3.6) is equivalent an additional 6 percent of citrus export value.

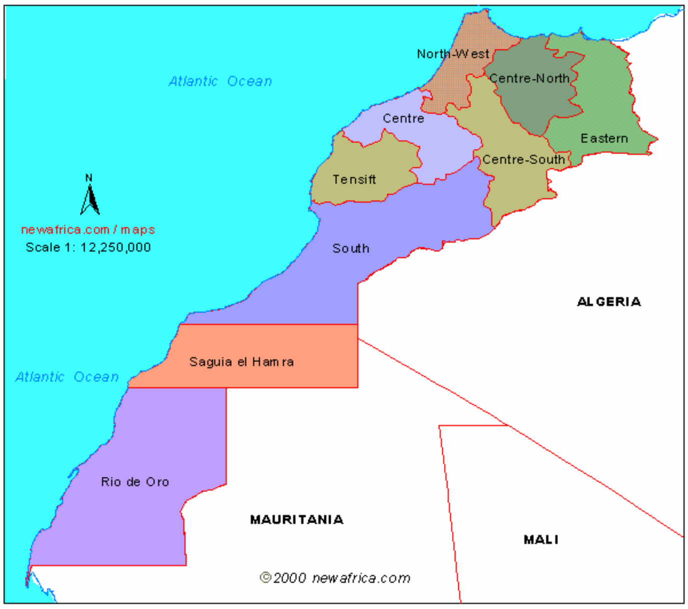

FIG. A3.2. Administrative map of Morocco and adjacent areas.

Overall, based on the available data, SIT is very competitive with insecticides for Medfly control in Morocco. Narrowly focused programmes on crop areas at risk may be more cost-effective than those aiming at areas neighbouring wild hosts where additional areas over and above commercial hosts would need treatment. Areas with lower densities of wild hosts offer much greater returns, for example suppression in the Northeast gives an annual benefit almost four times the SIT control cost, while in the South zone it is just less than twice the cost. If SIT eradication programmes were put in place, strict quarantine would need to be implemented to protect Moroccan areas from threatening infestation that may come from neighbouring countries, especially from Spain and Algeria. Permanent control requires a serious management that will have the task of preventing new invasions as previously had been done for other pests such as the New World screwworm in Libya.

A3.4 Conclusion

The market for sterile Medfly in Morocco depends upon the decision about the scale of the project and the respective area in commercial or total (commercial and wild) hosts. Given the limitations of the data underlined in this report and the assumptions used to overcome such constraints, area-wide SIT has been assessed for both suppression and eradication programmes. Up to 10 and 56 billion flying sterile males would be needed each year, respectively, for suppression and eradication strategies; the long-term needs for each strategy would be approximately 9.3 billion and 12.9 billion, respectively[24]. The weekly density of sterile males needed would be 100 000 flies per km^2 to be released over a period of 40 to 52 weeks/year in the four main fruit production zones. The high density of wild host reservoirs of Medfly must be taken into account in any attempt at pest suppression or eradication, particularly in the South of Morocco.

A 10-year cost/benefit analysis shows that net present value is positive. Those results should be considered within the limitations of the data provided, however they may encourage Moroccan officials to move ahead with implementing SIT. A public relations programme will be required to address the awareness of SIT schemes. By making them sensitive to the economic and environmental benefits, producers are more likely to take advantage of this pest control option.

To conclude, if any SIT is implemented in Morocco, the government should supervise the transition from insecticide control to SIT control. SIT demonstrations would be required and Berkane Region (Northeastern) is recommended for the pilot project to begin area-wide Medfly control. When the pilot project is fully operational, the programme could be broadened to other Moroccan regions.

A3.5 References

References in individual Annexes may have “a”, “b” etc. following the publication date, this refers to the way they appear in the main report’s Section 9.1 Bibliography, where all references are listed.

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Annex 4
On-site study of the market for sterile Medfly in Tunisia

Citrus production has stagnated and exports have decreased in recent years mainly due to lack of quality. The CB analysis assumed no increase in areas so the results remain valid. The benefits may even be higher in the future for two reasons: citrus is underperforming but it is considered one of the sectors which has the potential to be competitive (World Bank, 2006); malathion has recently been withdrawn from the list of authorised substances in the EU, and adjustments to the MRLs are anticipated to come through on the short term. Alternatives to malathion are five times more expensive.

The Sterile Fly Production facility started producing flies for release in the Cap Bon area during 2004/2005, Production levels are still variable but the average number of pupae/week during the last weeks of 2005 was 5 million (M'saad Guerfali, 2006). In November 2005, GIF (Groupement Interprofessionnel des Fruits), the citrus industry association, invested in an holding and emergence unit which is located in Cap Bon close to the sterile release area.

A4.1 Introduction

Tunisia has a history of three pilot projects using the sterile insect technique for the control of Mediterranean fruit fly (*Ceratitis capitata* Wiedemann), also known as Medfly. The first project implemented in northern Tunisia in the 1970s relied upon local and experimental production of sterile flies, while the second, which took place in the Southern Oases of Tozeur Governorate in 1994, made use of genetic sexing strains (GSS) Medfly pupae produced in the IAEA laboratories. The present project supported by IAEA under its Technical Cooperation Programme relies on a small-scale rearing facility (weekly production capacity of 8 to 12 million sterile pupae) constructed by the Centre National des Sciences et Technologies Nucléaires (CNSTN) in Sidi Thabet to supply the needs of a 15 000 ha pilot test over citrus groves in the Cap Bon Peninsula where SIT is currently being validated. The CNSTN supplies the sterile flies, the Ministry of Agriculture takes care of the field operations and GIF (Groupement Interprofessionnel des Fruits), formerly known as GIAF (Groupement Interprofessionnel des Agrûmes et Fruits) has contributed a holding and emergence unit. This acceptance of the SIT approach and the increasing concerns about market competition and environmental and health degradation due to excess insecticide use are reasons why Tunisia is regarded as a favourable location for the uptake of SIT for control of the Medfly over larger areas.

This study is intended to estimate the amount of sterile Medfly pupae that would be needed in control programmes in the Cap Bon region of Tunisia. It assumes that the market is for continued suppression rather than eradication due to the continued presence of flies in neighbouring areas and the presence of major roads through the region. It is also assumed that the programmes will be largely managed by the government with an element of private involvement. The possibility of expanding the control programme to other areas is also discussed.

The Tunisian authorities perceive an opportunity to increase their export revenues by providing a high quality pesticide residue free product to the European markets. At the same time, they also realize the advantages of lower pesticide use to the health of their citizens and the quality of the environment. A preliminary programme has been tried in the country and recently a pilot scale facility for the production of sterile flies has been completed. Baseline surveys of fly number and the distribution of wild and cultivated hosts have also been undertaken.

The main basis for the estimate of fly numbers is a study on the cost-benefits of a SIT programme for the Cap Bon region; other regions of the country have not been considered but do represent a potentially large requirement for sterile Medflies.

A4.2 Scope of the analysis

The analysis was not exhaustive and assumptions will need to be evaluated whenever new data are available in the future. A longer term study may reveal more precise figures for the value of fruit production and sales, fruit prices, the production areas worth treating and the actual damage to each variety of fruit from Medfly (versus from other causes). Table A4.1 gives details of the information that was available, the source and the level of confidence of the data being reliable.

Table A4.1. Analysis of data for determining the market for sterile male Medfly in Tunisia

Data type: losses caused by Medfly	Source	Confidence	Explanation
Fruit areas	GIF	good/moderate	areas of fruit available for each Délégation but areas of new plantings only available for Tunisia as a whole
Fruit prices	GIF	moderate/good	prices available for exported oranges (5 yr average) and local market prices. But about 85% of fruit not sold through market and only expert opinion is available for the price. some prices are not available and expert “guesses” are used
Fruit exports	GIF	Good	export figures available
Fruit yields	GIF	moderate/good	yields for Tunisia used to calculate yields for Cap Bon so there may be local differences that will not be included
Cost of chemical control: Aerial Ground	SONAPROV GIF/CRDA/ INRAT	good moderate	figures for cost per ha, number of treatments and ha treated for citrus crop very good some variability in prices for chemicals and number of treatments recommended.

Losses to Medfly (with and without control)	GIF/INAT/ INRAT/DGPV /CRDA	moderate/poor	some reliable information for citrus but less reliable for other fruits. Expert opinion used to fill gaps
Fly release	SONAPROV	good/moderate	quote from company but not sure of plane specification required so some doubt here
Local prices	CNSTN	good/moderate	prices for labour etc generally reliable but rather broad in nature
Discount rate	UN	Good	official figure from Monthly Bulletin of Statistics Online http://esa.un.org/unsd/mbsdemo/mbssearch.asp
Publicity		moderate	estimate by consultant, in consultation with others, of money required to mount good publicity prior to and during SIT programme
See Section A4.7 for sources of data			

A4.3 The study area

The Cap Bon region is located in the north east of Tunisia, a peninsula surrounded by the Mediterranean Sea. This makes it particularly suited to a SIT programme since reinvasion is unlikely from the sea and the landward side is fairly arid in most places.

The entire peninsula covers an area of approximately 300 000 ha and grows a diversity of fruit in fertile soils. The tourist industry is important in the south of the region around Hammamet.

The Cap Bon region could lend itself to an eradication campaign but this would involve internal quarantine to prevent reinvasion of the area with Medfly from other fruit producing regions in the country. For this reason area-wide suppression is the only feasible option.

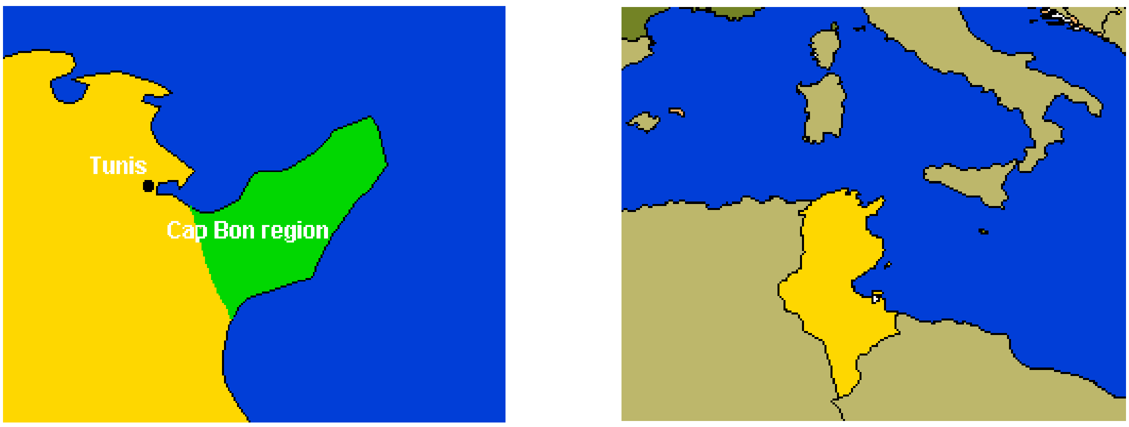

FIG. A4.1. Maps of Tunisia and of the Cap Bon region.

A4.4 Overview of Medfly problem in Cap Bon region

There are many suitable hosts for the Medfly in the Cap Bon region and the climatic conditions are also very suitable for its development and survival. The general population trend is for the minimum number of flies to be present around early spring in February and March. Shortly after this, stone and pome fruits such as peaches, apricots, apples and pears become available and the Medfly populations build up rapidly through the summer resulting in very high numbers being present at the time of the development of the citrus crop, resulting in serious losses.

Control is done on the early fruit crops by spraying from the ground using hydraulic sprayers, typically three applications to reduce the impact of the Medfly. Control on the citrus is primarily from the air by a contractor although there are some regions where aerial applications are banned (around Hammamet). Typically four to five sprays are applied each year. Whether the spray is from the air or on the ground the chemical used is malathion mixed with a protein bait.

A4.4.1 Fruit production

Citrus

Citrus is the main crop grown in the region and covers approximately 12 500 ha. There are a number of different varieties grown which means that citrus are present for most of the year providing a suitable host for Medfly. The total yield of all types of citrus in the region is about 200 000 mt. Approximately 20 000 mt of citrus are exported from the region each year, the remainder of the crop being sold on the domestic market. The value of the citrus is about US$58.6 million. Fruit production appears to be increasing in Tunisia as a whole but figures for the Cap Bon region were not available immediately and had to be left out from the analysis. The expanding area would generally make the cost benefit analysis results more favourable.

Estimates of losses were generally difficult to come by but discussions with experts seemed to suggest that without control, losses of up to 55 percent were possible and losses with control were still as high as 12 percent. Both of these figures would indicate that SIT could bring about large savings compared to the current chemical control. Control is carried out from the air over the majority of the crop (about 10 300 ha) with three to five applications each year. Typically the remainder is treated by three ground applications of malathion bait spray.

Stone fruit (apricots, plums and peaches)

Apricots cover an area of about 180 ha, plums 530 ha and peaches 830 ha. Together they have a value of about US$1.82 million. These crops are particularly susceptible to the Medfly and allow the rapid build up of populations early in the year. Peaches and apricots typically receive three ground applied treatments a year but plums none at all. Damage levels are about 80 percent in untreated crops and 8 percent in treated crops.

Pip fruit (pears and apples)

Apples cover an area of about 515 ha and pears a further 475 ha. Currently no chemical controls are used on these fruits but they do suffer significant losses of about 70 percent. It is thought that chemical control could reduce this to about 36 percent. The crops have a combined value of about US$485 000.

Pomegranate
Pomegranate crops cover an area of about 1100 ha and have a market value of about US$841 000. No control is used on the fruit but losses are estimated at only about 2 percent.

Figs
Figs are scattered and cover an area of about 500 ha. No information could be found on the distribution of the crop within the region so for the purposes of the analysis they are divided equally among the délégations. No control is used and losses of up to 95 percent can occur.

Opuntia (prickly pear)
The official area of commercial production is 1450 ha but the plant itself is growing everywhere and is used to define field and property boundaries. It is an excellent host for Medfly and therefore poses a serious problem for the SIT programme. The cultivated areas provide a valuable crop and the area is said to be expanding although no figure could be found. The value of the crop is about US$384 000 but the distribution of the crop within the Cap Bon region is not available. It may be necessary to treat large areas of this plant to prevent rapid re-invasion during suppression.

A survey of distribution and abundance of *Opuntia* spp. was recommended by IAEA consultants in earlier studies. There are large numbers of this Medfly host around the fruit production areas and vegetable production areas, as this tree is used to delimitate the land of the growers. In the rest of the Cap Bon areas, some areas have a concentration of the plant, but these are not associated with other commercial production. There are also large areas with no Opuntia present. Improving data on the coverage of this plant, particularly as a volunteer plant, will improve estimates regarding the area to be treated.

Other fruit
Small areas of other fruits such as loquat, quince and mulberries are grown. There is a large area of grapes grown in the region (~16 000 ha) but the consensus is that little damage is done to the fruit, most of which is used for wine production. No control is carried out for Medfly in grapes and therefore no costs incurred. There may be some benefits to the grape industry if SIT is implemented although these are not included in the analysis.

A4.4.2 Current control

The vast majority of pesticide application is done by SONAPROV, a state owned company that applies malathion bait spray from the air using Micronair sprayers. This is only applied to the citrus crop and is paid for by GIF, which is funded by the government. Therefore, the control of Medfly in the citrus crop is paid for and controlled by the government or its agencies. Farmers are not required to act to control Medfly in citrus. The aerial applications are restricted to 10 300 ha of the total of 12 500 ha because no aerial applications are permitted around the Hammamet region, the main tourist region. Aerial release of sterile flies would be allowed in this area, with the proper public relations to assure the population that the planes are not applying pesticides. There are typically three to five applications per year resulting in a total area treated of around 40 000 ha. This is because not all areas receive the same number of treatments, a reduced area being treated later in the season. The total cost of the treatment is around US$380 000 per year.

In general, the cost of control from the air is lower than using ground applications. The planes are used for control operations against other pests in different parts of the country at other times of the year.

Control using hydraulic sprayers and handheld lances is used in the remaining areas against Medfly on citrus. Malathion bait spray is the control used. Bait sprays are used in the same way on other fruit crops. There has not been any analysis of the option of using bait sprays on an area-wide basis in place of SIT or the current practices.

It would appear that the control is not very effective, whether from the air or on the ground. Very high residual losses are still being experienced in a number of crops. This is no doubt due to the high pressure from the flies that survive well in the prevailing conditions. Although trapping programmes have not been conducted in all parts of Cap Bon, the areas surveyed annually show that Medfly populations are very high during the summer months. The pattern of the population fluctuation is the same all around the peninsula.

A4.5 The cost benefit model

The model was developed using Microsoft® Excel and has a degree of flexibility within it to test a number of different scenarios. As with all models, the interpretation of the results should be done bearing in mind the uncertainties in the data.

A4.5.1 Input to the model

The model comprises the following input sheets (see Section A4.8).

Fruit areas
This sheet contains the areas of each type of fruit grown in the Cap Bon region divided up by délegation. The total area of fruit in the region is approximately 19 000 ha.

Fruit prices
This sheet contains information on the prices for the different fruits at the wholesale market. The price for the export of oranges is also included. About 85 percent of the fruit does not pass through a wholesale market but is marketed more directly. The price for fruit outside the wholesale system is very similar to that within. The same price was used for all fruit except for the 20 000 mt of oranges exported.

Yields and value
The sheet shows the yield of each crop grown and the value of the crop in US$ by délégation. The yields have been calculated from the national production areas and tonnages produced and therefore may be inaccurate as the yields in the Cap Bon region may well differ from the national average.

Losses
This sheet shows the yield losses attributable to Medfly for each of the significant fruits grown in the region. The figures show the losses that occur when there is no control and those that occur when current control measures are used. For many of the crops no control is used whatsoever resulting in large losses. However, even where control is used there are significant losses occurring. The value of these losses is given in US$ and amount to some US$9.5 million per year with the current control programme, the majority coming from citrus.

Control
The number of control operations that are used on each crop are detailed in this sheet along with the cost of those control activities. There are two main categories, the aerial control programme and the ground spraying. The air applied bait figures are for the year 2000, but are typical of the area treated. The cost of these operations is presented based on the figures from SONAPROV and the figure given in the fruit prices sheet.

SIT
This sheet covers the costs of an SIT programme such as pre- and post-SIT monitoring, publicity, staff training, pre-eradication chemical control and general administration. The cost of running the release centres, the price of the flies and release operations are included here.

The price of imported sterile Medfly is likely to reach US$400 per million sterile male Medflies by late 2002, not including transport. Although studies by potential suppliers originally set a value of $350 (Novotny *et al.*, 2001), the largest producer of Medfly, El Pino in Guatemala, has re-estimated their costs to be US$233 per million and other studies are using higher figures as well (e.g. Mumford and Larcher-Carvalho, Annex 2 of this project report).

If the pilot production facility in Tunisia is able to provide all of the sterile male Medfly needed, the costs per unit may be much lower, but the projected costs/price should include the capital cost of construction if the government is to quantify the SIT option accurately (see Section 6 and 7). Economies of scale and improvements with experience over time can reduce costs (Ortiz, 2002), however, rising labour rates in particular will keep the costs rising (see Section 7 and Annex 1).

From his studies, Ortiz (2002) set the costs for aerial release of flies at 7.5 cents per ha instead of the price of $3.73/ha used in this study. The higher price was quoted by those carrying out the pesticide applications at the time of the visit in the summer of 2001. This variation in cost of aerial release or applications creates a large variation in the model and should be rectified if possible.

A4.5.2 Assumptions

A4.5.2.1 Data

The cost benefit model contains a number of assumptions that need to be borne in mind when the results are examined. The assumptions are necessary for a variety of reasons. Firstly, some data are inherently inaccurate; secondly, there was insufficient time to collect all the data that are desirable; thirdly, there was not always agreement on the values for infestation and damage etc. that were provided by the experts and fourthly, data were only available at a greater spatial scale than desirable. Where disagreement occurred about values a consensus was sought, but did not necessarily result in accurate values. Where the spatial scale was incorrect, average values from the national data were substituted. The model provides the current best estimate of costs and benefits but is not 100 percent accurate for the above reasons.

A4.5.2.2 Scenarios

The scenarios covered a number of different options all based on the suppression of the Medfly population rather than a national eradication campaign. The first scenario is based on treating all the fruit bearing areas in the region, buffer zones and the area around the coast where there are a number of small towns and villages that produce a small amount of fruit. The centre of the peninsula is left untreated as this area is arid and has very few if any Medfly hosts.

The second scenario considers treating only the citrus growing areas and a buffer strip around those areas. This results in a smaller area being treated but the benefits are considerably smaller as other fruit is not protected so well.

Two alternatives to the supply of flies are considered, firstly imported flies and secondly locally produced flies from the pilot factory or a yet to be constructed facility. CNSTN have expressed a desire to build a 500 million fly per week factory in order to supply potential demand for sterile Medfly in the Mediterranean region. The analysis considers a 60 million and 500 million fly per week facility.

The releases would have to be carried out on a weekly basis requiring a maximum of about 60 million flies per week.

At the time of the visit the current distribution and abundance of the Medfly in the region was not clearly known nor was the distribution and abundance of Opuntia. For the purposes of this analysis it is assumed that Opuntia is ubiquitous and the Medfly is present everywhere at high levels and therefore the level of treatment required is the same all over the region. This may be unduly conservative and it may be that the area treated could be reduced, resulting in reduced costs.

The analysis makes no allowance for any changes in the industry such as the expansion of the area of fruit being grown. The only figures available were the expansion of the area nationally which could not be used to provide estimates for the region. The general feeling was that the industry was expanding and this would tend to make any future operation more cost effective and result in a greater demand for flies. Other changes in the industry may result from changes in the types of pesticide permitted for use on fruit crops. Should organophosphates be banned either for domestic use or by preferred markets the only chemical alternative currently available is about five times more expensive than the current controls. Benefits also will change as the external market changes. Tunisia will discover in the next few years the impact of changes in markets, such as the European Union’s latest restriction on pesticide residues.

Finally, allowance has been made for the potential environmental benefits of SIT over conventional chemical control. No figures for pesticide pollution or poisonings were available. This component has been included in the analysis as a fixed cost per US$ of pesticide used in this case US$2 environmental and health damage for every US$1 spent on pesticide. Whilst this figure is included it should be treated with some caution but it has been used in other studies and was suggested by Pimentel *et al.* (1993).

The final assumption is that the resulting increase in fruit production can be absorbed by the markets and does not result in a decrease in price. Without expensive market studies it is impossible to say whether that is the case. This assumption will tend to overvalue the benefits arising from Medfly eradication. Conversely, there should be an increase in the production of fruit with lower levels of pesticides or even organic fruit which could be sold into the lucrative European market. Again the potential for this is not currently known. Since one of the market assumptions is negative and the other positive, it is possible, then, that the two cancel each other out and this is the approach adopted here.

A4.5.3 Costs due to Medfly

1. **Direct costs**. The cost of pesticide application to the fruit industry in the Cap Bon region amounts to some US$686 162 per year. This includes the aerial sprays to the citrus and the ground applied sprays to some citrus and other fruit crops.
2. **Residual losses**. The value of fruit lost despite treatment with insecticides is very large and is about US$10 500 000 per year. This appears to indicate that the present control is ineffective and still results in significant losses.
3. **Indirect costs**. The cost of the application of pesticides on the environment and health is a figure that has been taken from other similar studies. There is no evidence to support or refute the figures included in the analysis. However, common sense and other research indicate that toxic chemicals, however carefully used, will have some effect on the surroundings due to ignorance and accidents. The costs in this analysis have been estimated at US$537 600 per annum.

Other costs, which were not included in the model, are the impact of current control on secondary pests and the benefits to back yard fruit production that will come from the programme.

A4.5.4 Sterile Medfly requirements for SIT

The total number of flies required for release under the different scenarios has been determined according to the area of land to be treated and the type of host plant present. To treat the Cap Bon region approximately 60 million flies per week would be required to treat all the fruit production area and the areas where Opuntia was abundant. If the area treated was limited to the citrus area and a buffer zone surrounding it only approximately 32 million flies per week would be required. The relatively low number required would be supplied most cheaply by buying in flies.

As in other SIT control programmes, the benefit/cost for this operation is sensitive to the cost of the flies and the cost of release. There is a positive benefit/cost ratio with fly prices rising up to US$750 per million live flies delivered (this allows for mortality in transit). If flies are less expensive then the figures become more profitable.

There are other large areas of Tunisia and the adjoining countries where SIT technology may be suitable and these probably have similar production and economic conditions. However, without information on areas and levels of production, prices, losses and cost of control it is not possible to say if a market exists for flies in these areas.

A4.6 Conclusions

Although additional data are needed for a more in-depth analysis, it is clear that the benefit/cost of using sterile Medfly in Tunisia is positive and the concept is of great interest to the country. The demand will be between 32 and 60 million sterile male Medfly per week during the weeks of the year when control is appropriate (estimated as the entire 52 weeks by

Ortiz, 2002). As this will be a suppression programme, this demand will be ongoing. It will be important to continue to highlight the advantages of this technology after the initial years when growers may have forgotten the costs of the status quo damage and treatments of today.

A4.7 References

M'saad Guerfali, M 2006. L'Unité Pilote de Production des mâles stériles de la Cératite de Sidi Thabet. Presentation at the Cleanfruit Conference in Hammamet, Tunisia, 28 January 2006.

Novotny, J., Kozanek, M. & Beans, L.J. 2001. *Feasibility study for sterile insect mass-rearing facility in the Republic of Slovakia.* Final Report of IAEA Project SLR5002. Forest Research Institute in Zvolen, Slovak Republic and IAEA, Vienna, Austria.

Ortiz, G. 2002. Emails with MM Quinlan in discussion of the situation in Tunisia.

Pimentel, D., Acquay, H., Biltonen, M., Rice, P., Silva, M., Nelson, J., Lipner, V., Giordano, S., Horowittz, A. & D'Amore, M. 1993. Assessment of environmental and economic costs of pesticide use. *In* D. Pimentel & H. Lehman, eds. *The pesticide question: environment, economics and ethics.* London, Chapman & Hall.

World Bank. 2006. Tunisia Agricultural Policy Review. Report n. 352359-TN, pp144.

Reference for Section A4.8

Knight, J.D. 2001. Cost/benefit economic analysis of SIT for controlling Medfly in the Cap Bon area. Report for IAEA Project *Establishment of a Medfly mass-rearing facility and introduction of a pilot sterile insect technique control programme*" C3-TUN/5/020-03 01. Vienna, IAEA.

Sources of data for Table A4.1

Centre National des Sciences et Technologies Nucléaires (CNSTN)
Groupement Interprofessionel des Fruits (GIF)
Institut National Agronomiques de Tunisie (INAT)
Société Nationale de la Protection des Végétaux (SONAPROV)
United Nations (UN)
Institut National de la Recherche Agronomique de Tunisie (INRAT)
Commissariat Régional de Développement Agricole (CRDA)
Directeur Général de la Protection des Végétaux (DGPV)

A4.8 Appendix. Input for the cost benefit model

Fruit areas for Cap Bon

Total area of Cap Bon approx (Ha)	300,000
Total area of fruit	19125

Total cultivatable land (Ha)	186,000
Forests etc (Ha)	60,000
Other (Ha)	54,000

Total Area Ha (bearing)

	Pears	Apricots	Peaches	Pomegranate	Plums	Citrus	Loquat	Apples	Opuntia	Figs	Mulberry	Coings	Total
	475	180	830	1100	530	12460	220	515	1450	500	510	355	19125
Menzel BouZelfa	8	0	19	55	17	3513	34	7	145	50	8	150	4006
Beni Khalled	42	7	80	400	117	3013	42	14	145	50	22	52	3984
Solimen & Takelsa	87	5	125	130	37	2114	14	63	145	50	35	81	2886
Grombalia	168	37	258	21	64	571	28	251	145	50	15	27	1635
Bou Argoub	49	6	65	85	60	1552	20	25	145	50	13	10	2080
Hammamet	35	18	76	37	30	527	48	61	145	50	30	10	1067
Nabeul	31	66	84	154	79	397	15	25	145	50	235	4	1285
Korba	23	34	105	84	104	461	15	17	145	50	66	9	1113
Kelibia	30	5	10	118	17	67	3	50	145	50	76	11	582
Manzil Temime	2	2	8	16	5	245	1	2	145	50	10	1	487
Total	475	180	830	1100	530	12460	220	515	1450	500	510	355	19125

Prices

15% of fruit passes through market

Market price Bir El Kassaa (5 year average 1995-2000)

Citrus	Quantity Tonnes	Price D/T	Value
O Maltaises	7714	319	2460766
Clementines	6488	637	4132856
Mandarins	1536	384	589824
Lemons	4299	547	2351553
O Douces	3653	495	1808235
O Divers	6280	677	4251560
C Beldi	8	1148	9184
Limes	177	1252	221604
Grapefruit	215	540	116100
Total	**30370**	**Average**	**524.92**
Apricots	5695	488	
Almonds	3296	507	
Cherries	53	3025	
Figs	1810	699	
Nefles	925	612	
Peaches	9242	764	
Pears	10138	677	
Apples	11897	685	
Plums	6235	995	
Coings	504	295	
Pomegranate	5803	341	
Opuntia		1200	
other fruits		600	
O Valencia		500	
O navels		500	
Other citrus		500	

Quantities for all of Tunisia

Export prices

	Average		1996		1997		1998		1999		2000	
	Quantity	Price	Quantity	Price	Quantity	Price	Quantit	Price	Quantit	Price	Quantity	Price
Citrus	21754.6	566.8	21732	524	16084	635	22776	535	21178	600	27003	540
Apricots	252.2	1388.6	87	1895	232	1160	355	1338	426	1350	161	1200
Pomegranat	690.6	741.2	744	743	289	583	634	839	724	787	1062	754
Almonds (fre	140.2	958.2	141	1200	71	803	129	916	173	922	187	950
dry	221.8	2370	486	2646	74	2695	149	2714	70	2250	330	1545
Other fruits	306.8	1096.2	0		28	1920	15	2296	183	768	1308	497

20,000 tonnes of Maltaises oranges exported from Cap Bon

Yields in areas and value of crop

Exchange rate	1.5 DT:1US$

Total yield (tonnes)

	Pears	Apricots	Peaches	Pomegranate	Plums	Citrus	Loquat	Apples	Opuntia	Figs	Mulberry	Coings	Total yield
Totals	**600.00**	**610.00**	**1493.00**	**3700.00**	**1305.00**	**200300.00**	**1180.00**	**470.00**	**480.00**	**595.00**	**250.00**	**1050.00**	**432333.00**
Menzel BouZelfa	10.11	0.00	34.18	185.00	41.86	63000.00	182.36	6.39	48.00	59.50	3.92	443.66	**134619.14**
Beni Khalled	53.05	23.72	143.90	1345.45	288.08	54900.00	225.27	12.78	48.00	59.50	10.78	153.80	**119060.19**
Solimen & Takelsa	109.89	16.94	224.85	437.27	91.10	26300.00	75.09	57.50	48.00	59.50	17.16	239.58	**56581.05**
Grombalia	212.21	125.39	464.09	70.64	157.58	9600.00	150.18	229.07	48.00	59.50	7.35	79.86	**21741.37**
Bou Argoub	61.89	20.33	116.92	285.91	147.74	25450.00	107.27	22.82	48.00	59.50	6.37	29.58	**53264.67**
Hammamet	44.21	61.00	136.71	124.45	73.87	9250.00	257.45	55.67	48.00	59.50	14.71	29.58	**19530.15**
Nabeul	39.16	223.67	151.10	518.00	194.52	11800.00	80.45	22.82	48.00	59.50	115.20	11.83	**25439.24**
Korba	29.05	115.22	188.87	282.55	256.08	0.00	80.45	15.51	48.00	59.50	32.35	26.62	**1134.21**
Kelibia	37.89	16.94	17.99	396.91	41.86	0.00	16.09	45.63	48.00	59.50	37.25	32.54	**750.61**
Manzil Temime	2.53	6.78	14.39	53.82	12.31	0.00	5.36	1.83	48.00	59.50	4.90	2.96	**212.37**

Value ,000 US$,000

	Pears	Apricots	Peaches	Pomegranate	Plums	Citrus	Loquat	Apples	Opuntia	Figs	Mulberry	Coings	Total US$
Totals	**270.80**	**198.45**	**760.43**	**841.13**	**865.65**	**60,928.07**	**532.57**	**214.63**	**384.00**	**277.27**	**100.00**	**206.50**	**65579.51**
Menzel BouZelfa	4.56	0.00	17.41	42.06	27.77	18,288.01	82.31	2.92	38.40	27.73	1.57	87.25	**18619.97**
Beni Khalled	23.94	7.72	73.29	305.87	191.10	15,896.13	101.67	5.83	38.40	27.73	4.31	30.25	**16706.24**
Solimen & Takelsa	49.60	5.51	114.52	99.41	60.43	8,032.14	33.89	26.26	38.40	27.73	6.86	47.12	**8541.87**
Grombalia	95.78	40.79	236.38	16.06	104.53	2,938.68	67.78	104.61	38.40	27.73	2.94	15.71	**3689.37**
Bou Argoub	27.94	6.62	59.55	65.00	98.00	8,264.68	48.42	10.42	38.40	27.73	2.55	5.82	**8655.11**
Hammamet	19.95	19.85	69.63	28.29	49.00	3,323.08	116.20	25.42	38.40	27.73	5.88	5.82	**3729.25**
Nabeul	17.67	72.77	76.96	117.76	129.03	4,185.35	36.31	10.42	38.40	27.73	46.08	2.33	**4760.80**
Korba	13.11	37.49	96.20	64.23	169.86	0.00	36.31	7.08	38.40	27.73	12.94	5.24	**508.59**
Kelibia	17.10	5.51	9.16	90.23	27.77	0.00	7.26	20.84	38.40	27.73	14.90	6.40	**265.30**
Manzil Temime	1.14	2.21	7.33	12.23	8.17	0.00	2.42	0.83	38.40	27.73	1.96	0.58	**103.00**
						60928.07							

Yield calculations

Figures are for whole of cap Bon region
Average of 2000 and 2001

	Pears	Apricots	Peaches	Pomegranate	Plums	Citrus	Loquat	Apples	Opuntia	Figs	Mulberry	Coings	**Total**
Total Area Ha (bearing)	**475**	**180**	**830**	**1100**	**530**	**12460**	**220**	**515**	**1450**	**500**	**510**	**355**	**19125**
Total Yield(Tonnes)	600	610	1493	3700	1305	193350	1180	470	480	595	250	1050	
Yield (Tones/ha)	**1.26**	**3.39**	**1.80**	**3.36**	**2.46**	**15.52**	**5.36**	**0.91**	**0.33**	**1.19**	**0.49**	**2.96**	

Yield losses

	Pears	Apricots	Peaches	Pomegranate	Plums	Citrus	Loquat	Apples	Opuntia	Figs	Mulberry	Coings
Losses - no control	0.70	0.80	0.80	0.02	0.80	0.55	0.80	0.70	0.80	0.95	0.70	0.70
Residual losses	0.36	0.08	0.08	0.02	0.08	0.12	0.05	0.36	0.80	0.57	0.36	0.36

Losses no control ***values in ,000 US$***

	Pears	Apricots	Peaches	Pomegranate	Plums	Citrus	Loquat	Apples	Opuntia	Figs	Mulberry	Coings	Total US$
Total	**324.96**	**79.38**	**661.25**	**17.17**	**752.74**	**38,080.04**	**448.48**	**234.76**	**1,536.00**	**612.57**	**109.38**	**225.86**	**43,082.58**
Menzel BouZelfa	4.99	0.00	15.14	0.86	24.14	11,430.01	69.31	3.19	153.60	61.26	1.72	95.43	**11,859.64**
Beni Khalled	26.19	6.71	63.73	6.24	166.17	9,935.08	85.62	6.38	153.60	61.26	4.72	33.08	**10,548.79**
Solimen & Takelsa	54.25	4.79	99.59	2.03	52.55	5,020.09	28.54	28.72	153.60	61.26	7.51	51.53	**5,564.45**
Grombalia	104.76	35.47	205.54	0.33	90.90	1,836.67	57.08	114.41	153.60	61.26	3.22	17.18	**2,680.42**
Bou Argoub	30.55	5.75	51.78	1.33	85.22	5,165.43	40.77	11.40	153.60	61.26	2.79	6.36	**5,616.23**
Hammamet	21.82	17.26	60.55	0.58	42.61	2,076.93	97.85	27.81	153.60	61.26	6.43	6.36	**2,573.05**
Nabeul	19.33	63.27	66.92	2.40	112.20	2,615.84	30.58	11.40	153.60	61.26	50.40	2.54	**3,189.75**
Korba	14.34	32.60	83.65	1.31	147.71	0.00	30.58	7.75	153.60	61.26	14.15	5.73	**552.67**
Kelibia	18.71	4.79	7.97	1.84	24.14	0.00	6.12	22.79	153.60	61.26	16.30	7.00	**324.52**
Manzil Temime	1.25	1.92	6.37	0.25	7.10	0.00	2.04	0.91	153.60	61.26	2.14	0.64	**237.48**

Losses with control ***values in ,000 US$***

	Pears	Apricots	Peaches	Pomegranate	Plums	Citrus	Loquat	Apples	Opuntia	Figs	Mulberry	Coings	Total US$
Total	**152.33**	**17.26**	**66.12**	**17.17**	**75.27**	**8,308.37**	**28.03**	**120.73**	**1,536.00**	**367.54**	**56.25**	**116.16**	**10,861.23**
Menzel BouZelfa	2.57	0.00	1.51	0.86	2.41	2,493.82	4.33	1.64	153.60	36.75	0.88	49.08	**2,747.46**
Beni Khalled	13.47	0.67	6.37	6.24	16.62	2,167.65	5.35	3.28	153.60	36.75	2.43	17.01	**2,429.45**
Solimen & Takelsa	27.90	0.48	9.96	2.03	5.25	1,095.29	1.78	14.77	153.60	36.75	3.86	26.50	**1,378.18**
Grombalia	53.87	3.55	20.55	0.33	9.09	400.73	3.57	58.84	153.60	36.75	1.65	8.83	**751.37**
Bou Argoub	15.71	0.58	5.18	1.33	8.52	1,127.00	2.55	5.86	153.60	36.75	1.43	3.27	**1,361.79**
Hammamet	11.22	1.73	6.05	0.58	4.26	453.15	6.12	14.30	153.60	36.75	3.31	3.27	**694.34**
Nabeul	9.94	6.33	6.69	2.40	11.22	570.73	1.91	5.86	153.60	36.75	25.92	1.31	**832.67**
Korba	7.38	3.26	8.37	1.31	14.77	0.00	1.91	3.99	153.60	36.75	7.28	2.94	**241.56**
Kelibia	9.62	0.48	0.80	1.84	2.41	0.00	0.38	11.72	153.60	36.75	8.38	3.60	**229.59**
Manzil Temime	0.64	0.19	0.64	0.25	0.71	0.00	0.13	0.47	153.60	36.75	1.10	0.33	**194.81**
	152.33	17.26	66.12	17.17	75.27	8,308.37	28.03	120.73	1,536.00	367.54	56.25	116.16	**$10,861.23**

Control

Page details current control practices - number of sprays on each crop

Current control

Number of sprays per year

	Pears	Apricots	Peaches	Pomegranat	Plums	CitrusAir	Citrus Ground	Loquat	Apples	Opuntia	Figs	Mulberry	Coings	Total
Menzel BouZelfa	0	3	3	0	0	5	3	0	0	0	0	0	0	
Beni Khalled	0	3	3	0	0	5	0	0	0	0	0	0	0	
Solimen & Takelsa	0	3	3	0	0	0	0	0	0	0	0	0	0	
Grombalia	0	3	3	0	0	5	0	0	0	0	0	0	0	
Bou Argoub	0	3	3	0	0	0	0	0	0	0	0	0	0	
Hammamet	0	3	3	0	0	0	0	0	0	0	0	0	0	
Nabeul	0	3	3	0	0	5	0	0	0	0	0	0	0	
Korba	0	3	3	0	0	0	0	0	0	0	0	0	0	
Kelibia	0	3	3	0	0	0	3	0	0	0	0	0	0	
Manzil Temime	0	3	3	0	0	0	3	0	0	0	0	0	0	
	0	3	3	**0**	**0**	**5**	**3**	**0**	**0**	**0**	**0**	**0**	**0**	

Cost of control

	Pears	Apricots	Peaches	Pomegranat	Plums	Citrus Air	Citrus Ground	Loquat	Apples	Opuntia	Figs	Mulberry	Coings	Total
Menzel BouZelfa	$0.00	$0.00	$2,128.00	$0.00	$0.00	$115,830.00	$193,424.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$311,382.00**
Beni Khalled	$0.00	$784.00	$8,960.00	$0.00	$0.00	$167,310.00		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$177,054.00**
Solimen & Takelsa	$0.00	$560.00	$14,000.00	$0.00	$0.00		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$14,560.00**
Grombalia	$0.00	$4,144.00	$28,896.00	$0.00	$0.00	$47,520.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$80,560.00**
Bou Argoub	$0.00	$672.00	$7,280.00	$0.00	$0.00		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$7,952.00**
Hammamet	$0.00	$2,016.00	$8,512.00	$0.00	$0.00		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$10,528.00**
Nabeul	$0.00	$7,392.00	$9,408.00	$0.00	$0.00	$48,510.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$65,310.00**
Korba	$0.00	$3,808.00	$11,760.00	$0.00	$0.00		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$15,568.00**
Kelibia	$0.00	$560.00	$1,120.00	$0.00	$0.00		$336.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$2,016.00**
Manzil Temime	$0.00	$224.00	$896.00	$0.00	$0.00		$112.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$1,232.00**
	$0.00	**$20,160.00**	**$92,960.00**	**$0.00**	**$0.00**	**$379,170.00**	**$193,872.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$686,162.00**

Aerial Control areas (2000)

	Total treated - up to 5 spra	Area treated - max
Menzel BouZelfa & Solimen	11700	3900
Beni Khalled	16900	4300
Nabeul	4900	1100
Grombalia & Bou Argoub	4800	1200
Total aerial treatment	**38300**	**10500**

Total hectares in the regions

Citrus Areas	12460
Menzel BouZelfa & Solimen	5627
Beni Khalled	3013
Grombalia & Bou Argoub	2123
Nabeul	858
Hammamet	527
Kelibia	67
Manzil Temime	245
	12460

Fly costs

			US$	
Flies from Guatemala			750	
Price per million				
Locally produced flies				
Price per million (500 M)			250	
Price per million (60 M)			700	

$250 is the cost of running factory, diet, labour etc
it does not include the build cost (see below)

Local costs

Pilot factory is being built at a cost of			650,000.00
Cost of fitting out factory			80,000.00
Flies produced per week			12,000,000
Cost for factory producing	60	million flies	3650000
Allowing for economies of scale			**2920000**

Release facility	
Air-conditioned premises for eclosion of flies prior to release	
	2,000.00

General prices

	DT	DT	US$
Cost of trap		0.2	$0.13
Cost of servicing trap		500	$333.33
Cost per trap/week		0.99	$0.66
Cost of wicks per year		2.5	$1.67
Life of trap (months)		3.6	$2.40
Cost of running 1 trap per year		**28.96**	**$19.31**
Pesticide costs			
Cost of Malathion/litre (GIAF - farmer price)		10	$6.67
Cost of Malathion/litre (Sonoprov)		6.5	$4.33
Cost of Spinosad/litre		250	$166.67
Cost of Protein/litre		6	$4.00
Cost of application			
Plane cost/Ha		5.6	$3.73
Insecticide+bait/Ha		9.25	$6.17
Aerial application/Ha		**14.85**	**$9.90**
Proportion of cost from pesticide per Ha		0.15	
Field spray cost			
Labour/Ha		6	$4.00
Insecticide+bait/Ha		50	$33.33
Cost/Ha		**56**	**$37.33**
Proportion of cost from pesticide per Ha		0.36	
	per month	per day	
Labour		10	$6.67
Driver	300	13.5	$9.00
Technician	350	16	$10.67
Manager	800	36	$24.00
Field labour		10	$6.67

Application cost of flies (estimated)			
		Assumes one truck load	
Transport from factory to airfield		per day to airfield	
Refrigerated truck		50000	$33,333.33
Cost per year over 5 years		16666	$11,110.67
Driver		3600	$2,400.00
Cost per km		1.2	$0.80
Distance (km)	100	120	$80.00
Yearly cost		20386	$13,590.67
Cost per ha		1.132555556	$0.76
Aerial application of flies/ha		6	$4.00
(Assume 1 plane can cover 3,000 Ha/day			
18,000 Ha/week)			
Total cost per ha			$4.76

Pesticide rate litres/Ha (ground)	
	2

SIT Eradication Inputs

Zones		Total area	All fruit ,000 US$ Losses with control	,000 US$ Cost of control	,000 US$ Value of crop	Citrus ,000 US$ Losses with control	,000 US$ Cost of control	,000 US$ Value of crop
Zone 1	**Kelibia**	**51800**	$229.59	$2.02	$265.30	$0.00	$0.34	$0.00
Zone 2	**Manzil Temime**	**54000**	$194.81	$1.23	$103.00	$0.00	$0.11	$0.00
Zone 2	**Solimen & Takelsa**		$1,378.18	$14.56	$8,541.87	$1,095.29	$0.00	$8,032.14
Zone 3	**Menzel BouZelfa**	**53700**	$2,747.46	$311.38	$18,619.97	$2,493.82	$309.25	$18,288.01
Zone 3	**Beni Khalled**		$2,429.45	$177.05	$16,706.24	$2,167.65	$167.31	$15,896.13
Zone 4	**Korba**	**53800**	$241.56	$2.02	$265.30	$0.00	$0.34	$0.00
Zone 4	**Bou Argoub**		$1,361.79	$7.95	$8,655.11	$1,127.00	$0.00	$8,264.68
Zone 5	**Nabeul**	**53300**	$832.67	$65.31	$4,760.80	$570.73	$48.51	$4,185.35
Zone 5	**Grombalia**		$751.37	$80.56	$3,689.37	$400.73	$47.52	$2,938.68
Zone 6	**Hammamet**	**34200**	$694.34	$10.53	$3,729.25	$453.15	$0.00	$3,323.08
Total			$10,861.23	$672.61	$65,336.22	$8,308.37	$573.38	$60,928.07

SIT Costs	**pre-erad ,000 $/Ha**	**erad ,000 $/Ha**	**post erad ,000 $/Ha**	**One off ,000 $**
Flies (imported)		0.039		
Flies (local)		0.0364		
Aerial release		0.004755037		
Reception/Eclosion facility				
Publicity	0.0005	0.0005		
Administration	0.0005	0.0005		
Monitoring eradication Pre and during	0.019306878	0.019306878		
Post eradication monitoring			0.009653439	
Pre-eradication surveys				500
Ground bait pre-eradication	0.0224			
Aerial bait pre-eradication	0.02376			
Total	**0.066466878**		**0.009653439**	**500**
	Local price	**0.061461915**		
	Imported price	**0.064061915**		
Discount rate	**5.88%**			

km per trap in post erad monitoring
5

Suppression scenario 1

Suppression - All fruit area with buffer zones, local, imported or local+imported options

			2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Year			**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Eradication zone/phase														
Source of flies	**Local+imported**													
Area in hectares			19125	19125	19125	19125	19125	19125	19125	19125	19125	19125	19125	19125
Buffer area			38250	38250	38250	38250	38250	38250	38250	38250	38250	38250	38250	38250
Total area			57375	57375	57375	57375	57375	57375	57375	57375	57375	57375	57375	57375
Costs ($ thousand)														
	Factory 12M		730.000											
	Survey		500.000											
	Bait	Orchard+other												
	Monitoring pre-erad													
	SIT	All host areas		3,644.352	3,644.352	3,644.352	3,644.352	3,644.352	3,644.352	3,644.352	3,644.352	3,644.352	3,644.352	3,644.352
	Monitoring													
	Total		**1,230.000**	**3,644.352**	**3,644.352**	**3,644.352**	**3,644.352**	**3,644.352**	**3,644.352**	**3,644.352**	**3,644.352**	**3,644.352**	**3,644.352**	**3,644.352**
	Proportion residual loss			0.7										
Benefits ($ thousand)														
	Current control			672.610	672.610	672.610	672.610	672.610	672.610	672.610	672.610	672.610	672.610	672.610
	Residual loss			7,602.862	7,602.862	7,602.862	7,602.862	7,602.862	7,602.862	7,602.862	7,602.862	7,602.862	7,602.862	7,602.862
	Environmental			490.116	490.116	490.116	490.116	490.116	490.116	490.116	490.116	490.116	490.116	490.116
	Total		**0.000**	**8,765.587**	**8,765.587**	**8,765.587**	**8,765.587**	**8,765.587**	**8,765.587**	**8,765.587**	**8,765.587**	**8,765.587**	**8,765.587**	**8,765.587**
Net (Benefit-Cost) ($ million)														
	Total		-1,230.000	5,121.235	5,121.235	5,121.235	5,121.235	5,121.235	5,121.235	5,121.235	5,121.235	5,121.235	5,121.235	5,121.235
	Cumulative		-1,230.000	3,891.235	9,012.470	14,133.705	19,254.940	24,376.174	29,497.409	34,618.644	39,739.879	44,861.114	49,982.349	55,103.584

NPV 10 yr	**31,909.437**
NPV 15 yr	**44,132.508**

Environmental & health costs US$/US$ pesticide spend	2
Buffer zone area (multiple of fruit area)	2
Fly release rate (proportion of 1000/Ha)	1

Suppression scenario 2

Suppression - Only citrus with surrounding buffer zones - costs and benefits only from citrus

			2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Year														
Eradication zone/phase														
Source of flies	**Local**													
Area in hectares			12460	12460	12460	12460	12460	12460	12460	12460	12460	12460	12460	12460
Buffer area			18690	18690	18690	18690	18690	18690	18690	18690	18690	18690	18690	18690
Total area			31150	31150	31150	31150	31150	31150	31150	31150	31150	31150	31150	31150
Costs ($ thousand)														
	Factory 60 M		2,920.000											
	Survey		500.000											
	Bait	Orchard+other												
	Monitoring pre-erad													
	SIT	All host areas		1,914.539	1,914.539	1,914.539	1,914.539	1,914.539	1,914.539	1,914.539	1,914.539	1,914.539	1,914.539	1,914.539
	Monitoring	Post-erad												
	Total		**3,420.000**	**1,914.539**	**1,914.539**	**1,914.539**	**1,914.539**	**1,914.539**	**1,914.539**	**1,914.539**	**1,914.539**	**1,914.539**	**1,914.539**	**1,914.539**
	Proportion residual loss			0.7										
Benefits ($ thousand)														
	Current control			573.378	573.378	573.378	573.378	573.378	573.378	573.378	573.378	573.378	573.378	573.378
	Residual loss			5,815.861	5,815.861	5,815.861	5,815.861	5,815.861	5,815.861	5,815.861	5,815.861	5,815.861	5,815.861	5,815.861
	Environmental			409.316	409.316	409.316	409.316	409.316	409.316	409.316	409.316	409.316	409.316	409.316
	Total		**0.000**	**6,798.555**	**6,798.555**	**6,798.555**	**6,798.555**	**6,798.555**	**6,798.555**	**6,798.555**	**6,798.555**	**6,798.555**	**6,798.555**	**6,798.555**
Net (Benefit-Cost) ($ million)														
	Total		-3,420.000	4,884.016	4,884.016	4,884.016	4,884.016	4,884.016	4,884.016	4,884.016	4,884.016	4,884.016	4,884.016	4,884.016
	Cumulative		-3,420.000	1,464.016	6,348.032	11,232.048	16,116.064	21,000.080	25,884.096	30,768.112	35,652.128	40,536.144	45,420.160	50,304.176

NPV 10 yr	**28,309.181**
NPV 15 yr	**39,966.072**

Environmental & health costs US$/US$ pesticide spend	2
Buffer zone area (multiple of fruit area)	1.5
Fly release rate (proportion of 1000/Ha)	1

Annex 5
Potential markets for sterile date moth for use in SIT

Ongoing research in Tunisia has now shown that *Ectomyelois ceratoniae* Zeller, the date moth or, in many countries commonly known as the carob moth, has characteristics that will allow development of genetic sexing strains (Mediouni-BenJemaa, 2005). Development of such strains will take years, but will reduce costs of field programmes of SIT considerably as well as reducing damage from feeding sterile moths (Franz, 2005). A new Technical Cooperation Project under IAEA is starting in Tunisia in 2007 aimed at building capacity for implementing area-wide SIT technology to address this pest problem (IAEA, 2007a). This indicates the continuing interest of that government in finding an environmentally benign pest control method for this species.

In many countries, such as Iraq and Iran, the primary host is pomegranate (A. Altaweel, pers. comm. 2005), and dates are rarely attacked during production. Mozaffarian *et al.* (2007) has shown that other less preferable hosts may provide over-wintering opportunities that then populate their preferred host in the next growth season. This may affect the coverage required for effective SIT once developed. Further research on this pest will continue to provide improved options for its control, including biological control agents that may be released simultaneously with sterile moths to bring some cost savings (Bloem *et al.*, 2005). Studies on control of other key date pests (such as *Ephestia cautella*) have taken place, although field trials have not been pursued. Eventually, SIT control of multiples species simultaneously will be possible if research continues to resolve present limitations in mass rearing and quality control.

Field performance of the irradiated date moth in Tunisia is discussed in Mediouni and Dhouibi, 2007. Commercial scale releases are not anticipated for several years, however, due to limited supply of sterile males and the need for additional research.

A5.1 Introduction

This study explores the potential market for the use of sterile date moth (*Ectomyelois ceratoniae* Zeller), a pest that has not been subjected to the sterile insect technique (SIT) beyond an experimental and limited field scale. Yet as progress is made on the technology for use of SIT in conjunction with other Integrated Pest Management (IPM) practices for control of this species, the potential market for sterile date moths – and plans for meeting this demand – are key factors for future success.

The use of various common and even scientific names for the date or carob moth hinders any market research. More challenging even, are the inconsistent data on distribution of the date moth. There is no doubt, however, that the wide distribution of date moth is the cause of extensive damage which either leads to severe losses in yield or to burdensome costs of annual control programmes in date producing areas, as well as in other susceptible commercial cropping systems.

The biological and technological criteria for the suitability of a pest to the SIT (Section 4.1) are all met or under active study for this species. The SIT will be particularly suitable against date moth as many of the date palms are grown in isolated oases (e.g. southern Tunisia) with limited risk for invasion. Significant progress has been made recently in the rearing of the date moth in Tunisia (see Section A5.1) but other requirements such as 1) the development of an efficient monitoring device, 2) the fine-tuning of the radiation biology and 3) the knowledge on the dynamics and behaviour of the sterile insects will be needed to complete the basic needs for suitability of this species to SIT.

Several of the countries that might benefit from SIT against date moth already have experience running SIT programmes with other species (e.g. Tunisia, South Africa, Argentina, USA). Those countries lacking experience could be supported by others in their region or by the international expertise in running SIT field programmes. What remains to be determined is the socio-economic benefits and willingness of the beneficiaries to pay for the costs of SIT. To do this, additional data are required on the actual infestation and damage levels to date palms and other commercial crops, social benefits from other host species that are not commercialized and costs of current control activities, including environmental costs.

More urgently, the reliance on methyl bromide (MB) for post-harvest control should be better quantified to determine the potential increase in demand for SIT in the next years as use of the fumigant becomes more restricted and in many cases disappears. Once this information is more precise, a major effort to educate and inform growers and governments of key date production countries may lead to the uptake of SIT for control of date moth on a large scale.

A5.2 Characterization

A5.2.1 Taxonomy and hosts

The date moth (*Ectomyelois ceratoniae* Zeller, or other scientific names noted below), also widely known as the carob moth, is a major pest in practically all countries producing date palm (*Phoenix dactylifera*). In certain countries, such as Algeria, Tunisia, Iraq and Iran, it is also an important pest of pomegranates (*Punica granatum*), affecting as much as 90 percent of that production. This pest also attacks pigeon pea (*Cajanus cajan*) and Indian tamarind (*Tamarindus indica*), which is referred to as its primary host in some literature (CAB International, 2001). One may surmise that another host, locust bean (*Ceratonia siliqua*), gave the pest its species name. Commercial hosts include citrus, carob, pistachio (see Mourikis *et al.*, 1998), almond, walnut, macadamia and practically any dried fruits. It also affects non-commercial species such as *Retama retam* and acacias. Although the date moth does not represent a threat to consumers, the damage from the pest greatly reduces the potential value of the crop and leads to pest control measures.

The date moth is in the order Lepidoptera, family Pyralidae and subfamily Phycitinae, and follows the behaviour of other pests in this subfamily. The distribution of the pest is not systematically documented and, in those cases that it is, the report often is unconfirmed or not official information. Some of the discrepancies in information available may be due to the various taxonomic names still employed, including:

- *Apomyelois ceratoniae* Zeller
- *Ectomyelois ceratoniae* Zeller
- *Myelois ceratoniae* Zeller

- *Ectomyelois phoenicis* (Durrant)
- *Myelois phoenicis* Durrant
- *Spectrobates ceratoniae* Zeller

as well as the range of common names, which are often shared by other species. It is most frequently cited as the date or carob moth, but has also been known as the knot-horn moth, blunt-winged moth, locust bean moth (England), Motte or Johannisbrot moth (Germany), "piral del algarrobo" in Spanish, "pyrale des caroubes" or "teigne des caroubes et des figues" in French, and "tignola delle carrube" in Italian (CAB International, 2001). This range of common names gives a flavour of the true distribution of what is rapidly becoming a cosmopolitan pest.

A5.2.2 Distribution of date moth

The pest is recorded as infesting much of continental Europe (CAB International, 2001) and is known to occur in the Mediterranean Basin region (e.g. Libya, Tunisia, Algeria and Morocco). While the year and manner of origin of the date moth in the Mediterranean region are unknown, there are references to moth infestations in date palms as long ago as the early 1800s. The species is said to occur throughout the former Soviet Union and the Middle East. Indeed while reported in Cyprus, Turkey, Israel, Lebanon, Iran, Iraq, and Saudi Arabia, the United Arab Emirates officials state that it does not occur in their territory[25]. Known to attack crops in India, it is unknown by officials and pest experts in Pakistan (Poswal, pers. comm. 2002)[26].

Despite the damage it causes to citrus, the species is not included in the European and Mediterranean Plant Protection Organization (EPPO) A2 Quarantine List (pests that occur in some parts of Europe but are not widely distributed and are subject to official control). This is because it is ubiquitous in the region and therefore does not strictly qualify as a quarantine pest in Europe.

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[25] Official sources claim the date moth present in UAE is *Batracchedra amydraula*, but deny the presence of the species reported on here. This is possible due to the drier climate. The same source identifies the other main pests of the date palm in the UAE as *Rhynchophorus ferrugineus* (the red palm weevil), *Meloidogyne incognita* (the root knot nematode), *Psammotermes hybostoma* (termites), *Parlatoria blanchardi* (date scale) and *Dysmicoccus brevipes* (a mealybug). It also notes fungal infections in the region, particularly *Fusarium* and *Phytophthora*, that are generally associated with borer activity, the latter creating access for fungal spores to the interior of the palm.

[26] Pakistan is a major date producer, reportedly earning between US$25 million and US$30 million annually from its date exports. Date production seems concentrated in the provinces of Sind and Punjab. The region of Khaipur, in the province of Sind, has over 40,500 ha in dates. Other potential hosts in Pakistan include pomegranates, which are mainly in Loralai district of Balochistan, and pistachio, which is not a commercially grown fruit tree but could serve as reservoirs for the pest.

There is no report of date moth in Pakistan (based on records and calls to officials by Ashraf Poswal, CABI Bioscience Centre, Pakistan). However, Pakistani date groves, especially those in Sind, were attacked in 1998 by a new insect pest, which the press (Ali Bhambhro, 2000) described as a lepidopterous pest. The same pest now re-appears each year at an unspecified time of the year. The infestation episodes are reported to follow a sequence whereby the insect larvae bore small holes near the fruit caps of young dates and cause them to drop prematurely. This description generally resembles the behaviour of the date moth. The Pakistani plant protection agency has not yet definitively identified the insect involved in these episodes. Losses due to this insect pest are reported to reach as high as 90 percent and are said to be characterized by an uneven distribution within the date groves, infesting some trees while leaving others unaffected. This infestation pattern is also associated with the date moth.

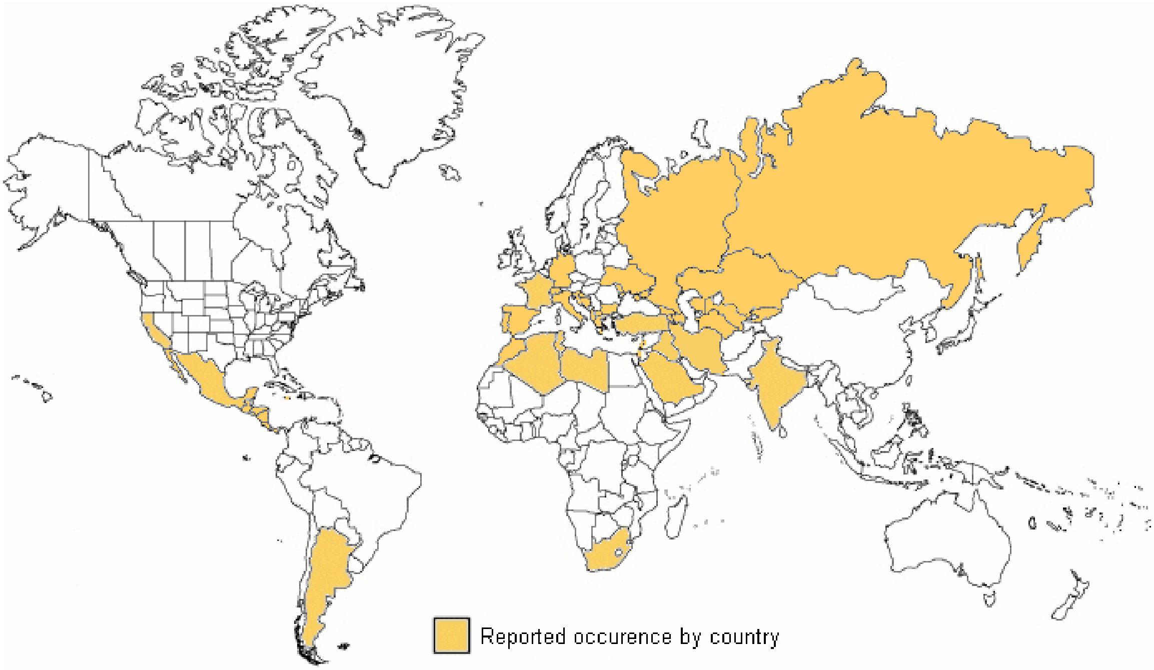

FIG. A5.1. An unofficial map of distribution of Ectomyelois ceratoniae Zeller based on references and interviews cited in this report.

Its range in Africa is throughout the North with infestation in South Africa as well; no published information was encountered on its presence in the vast region between. In the Western Hemisphere date moth is recorded in Argentina, Jamaica, Montserrat and Barbados (Schotman, 1989); it is believed to be in much of South and possibly Central America. There are unconfirmed reports in Mexico. The date moth, locally referred to as the carob moth, was first detected in California in 1982. Some texts refer to it as present throughout the southern USA. There is some indication that the species entered Australia in the past decade, but this report is unconfirmed.

No official distribution map of this species has been published. Official distribution data are limited to that provided or confirmed by a National Plant Protection Organization, the official plant health agency of each country. Much of the information for Figure A5.1 comes from informal papers or reports that should not be used for decisions about trade or quarantine. Furthermore, occurrence of a pest in any part of a country is shown as if it covers the entire country. (The exception is the USA, where only California is included.) Therefore, for example, reports of date moth throughout the Former Soviet Union appear to reach the far north. Distribution is shown based on our evaluation of the source. It is likely that the species has wider distribution of countries, yet is much more limited within countries, than shown in this map produced originally for this report.

A5.2.3 Damage from date moth

In the Mediterranean Basin countries, maximum development occurs during the spring and summer seasons when the temperature hovers around 30°C and the relative humidity is between 45 and 55 percent. When temperatures rise above 35°C, typically during July and August, they become lethal to the date moth and its development either decreases or ceases as the temperature changes. The optimum development temperature is between 25°C and 30°C

(Dhouibi, 1989, 1992, 2000). Population sizes and infestation levels depend on climate and the type of host fruit. Dry seasons or periods are best for high infestations levels (Dhouibi, 1982, 1989, Dhouibi and Jemmazi, 1993, 1995, 1996).

The pest causes significant damage on various crops throughout the Mediterranean Basin, but the damage caused by the date moth varies by region and by host plant (and variety). For example, for all Tunisian varieties of pomegranate, infestation levels reach 90 percent in the south of the country but only 15 percent in the north. In Iraq, where this species is also an important pest on pomegranates, infestation levels are around 45 percent. Infestation rates on dates reach 18 to 20 percent in Tunisia and 30 percent in Algeria; under packing house storage conditions in Tunisia, Algeria and Libya, levels reach more than 40 percent. On pistachios, infestation levels in Tunisia reach 75 percent (Dhouibi *et al.*, 1985, 1989). In general, date moth is an especially serious pest to stored products because of its rapid development under storage conditions.

Infestation rates in California are highest from August to November, when higher humidity causes fungi to grow on the surface of the fruit, which attracts the moths. Typical infestation rates are about 10 percent but can reach as much as 40 percent. Although all date varieties are susceptible to date moth infestations, the Deglet Noor variety is especially at risk. Annual economic losses caused by the date moth in California are estimated at US$1 million plus control costs (California Date Commission, 1998).

FIG. A5.2. Symptoms of infestation by date moth in citrus
Photo credit Nadia Al-Khateeb, by permission of the *Arab Scientist*.
http://www.arabscientist.org/english/gallery/insects/associate

Research in Morocco suggests that the date moth causes up to 30 percent yield losses in date production in Morocco (Boukaa *et al.*, 2001). The research identified three different species of moth infesting date palm trees – *Ectomyelois ceratoniae* (the date moth), *Plodia interpunctella* and *Cadra figulilella*. Of these, the latter two were considered to be secondary pests. Date infestation levels were found to vary yearly, with higher levels during rainy years. Date varieties with thin epidermis were more subject to infestations. Bagging the fruit clusters reduced infestation levels. The research also suggests that *E. ceratoniae* populations in fallen dates can be can be limited by two parasitoids – *Phanerotoma ocularis* and *Bracon hebetor*. Morocco suffers from a more damaging date disease, however, that influences decisions about control of date moth.

A5.3 Current control of date moth

A5.3.1 Post-harvest control measures

Generally, the most common strategy against the date moth in the Mediterranean region is post-harvest treatments consisting of fumigation of the harvested fruit in packing houses in order to prevent the maturation of the moth. A case in point is Morocco, where there are no efforts to control the date moth at the field level, but some of the commercial marketing enterprises fumigate harvested dry dates with aluminum phosphate. Soft dates are not fumigated because of the risk of chemical residues (Boukaa *et al.*, 2001). Even in countries that employ some field control, fumigation is common. In California, for example, harvested dates are routinely fumigated with methyl bromide or phosphine soon after harvest. In 1997, 851 kg a.i. of methyl bromide was applied post-harvest in California (Farrar, 2000).

In Tunisia, methyl bromide costs about US$300 per 50 kg and is applied at a rate of 85 g per mt for three hours. Failure to implement post-harvest treatment can result in losses as high as 40 percent of the harvested fruit. While the cost of the treatment is relatively inexpensive, the cost of the fumigation chambers is very high – between US$150 000 and US$200 000 per chamber. Presently, there are about 43 such chambers operating in Tunisia.

It is important to note, however, that in Tunisia, as in many other countries, the use of methyl bromide will be phased out once all the chemicals currently in stock have been depleted. Recent studies have shown that there is potential for using phosphine, heat treatment and the use of CO_2 as alternatives to post-harvest fumigation of dates with methyl bromide (pers.comm. Dhouibi, 2005).

While SIT cannot substitute the post-harvest fumigation treatment, as SIT is species specific and fumigation will kill all pests of dates, the disadvantages of post harvest fumigation make field IPM all the more important for the future.

A5.3.2 Field control measures

In some countries, nets or bags are used to cover dates and thereby protect the crop. In the USA, this strategy is used primarily in organic production sites.

The majority of field control efforts are aimed at suppression using biological control agents or microbial pesticides. The commonly used pathogen, *Bacillus thuringiensis kurstaki*, is also a natural control agent against date moth.

About 50 percent of the date fields in Tunisia (approximately 14 000 ha) are treated with *Bacillus thuringiensis* (*B.t.*) and the other half are treated with a variety of control methods, such as plastic bags, nets, and other devices. It takes about ten days to treat the 14 000 ha that are treated with aerial sprayings of *B.t.* and each site is treated three times per year. The cost per treatment is approximately US$35/ha – US$15/ha for the aircraft and US$20/ha for the control agent. The government pays for the expense and then recovers the cost from the producers. It is estimated that the total annual cost of treating 14 000 ha of date palm in Tunisia with *B.t.* is approximately US$350 000. Residual losses in date production are estimated to be less than 4 percent under high intensity production regimes and above 20 percent under low intensity regimes. These levels are achieved with combined measures under IPM.

In the Mediterranean Basin, for example, the highest level of efficacy of field treatments with *B.t.* is estimated at 70 percent while packing house fumigation with methyl bromide is considered to be 100 percent effective. Field applications of *B.t.* are also effective to some degree on all the related species of the *Ephestia* genus. In general, however, applications of *B.t.* alone are insufficient for date moth control. This is related to the very short period that the date moth larvae are free living before they enter the dates. More importantly, the preferred location of the first instar larvae is under the calyx of the dates, which is inaccessible to *B.t.* In addition, the biopesticide remains on the fruit for a very short time. The efficacy of the biopesticide is reduced further because the more effective method of the ground application is considered to be too costly by the government and it is not used in the fields. Farmers prefer aerial spraying for following reasons:

- it is less costly
- it can be applied rapidly
- it can be used in all the date growing regions.

Field releases of biological control agents against date moth, other than B.t., include the following parasitoids and predators (CAB International, 2001):

Parasitoids:
- *Apanteles angaleti*
- *Brachymeria aegyptiaca*
- *Bracon hebetor*
- *Clausicella suturata*
- *Dolichogenidea lactea*
- *Dolichogenidea ultor*
- *Goniozus legneri*
- *Mintho rufiventris*
- *Phanerotoma ocularis*
- *Trichogramma telengai,* which attack eggs
- *Venturia canescens*

Predators:
- *Blattisocius tarsalis*
- *Metaseiulus occidentalis*

The effectiveness of these agents against date moth is reportedly low.

Tunisian date producers overwhelmingly oppose the use of chemical field pesticides. Apparently, this reaction is largely based on their negative experience with previous attempts at using chemical controls for the eradication of locusts. Furthermore, in the mid-1990s the Government of Tunisia banned the use of chemical cover sprays for this purpose due to rising concerns about and greater restrictions of residue limits (IAEA, 2001c). As a consequence, there is little use of chemical pesticides at the field level. For this reason, there are no significant adverse pesticide impacts on human health under current date production practices in Tunisia and therefore no environmental benefits will be apparent using SIT, unlike in some other countries.

A5.3.3 Other approaches to field control

Field trials in Tunisia have demonstrated that pheromones for date moth produced by INRA in France are very effective in attracting date moth, but there is a problem of degradation of the pheromones in the field and the attractiveness of the pheromones to the male date moths is lost rapidly.

Presently *B.t.* is used for other purposes in the production areas in Israel and may be having some impact on date moth. The primary control against date moth, however, is routine sprays of synthetic pyrethroids (Navon, pers comm. 2001).

Conventional control has included cover sprays of organophosphate insecticides (IAEA, 2001c). Other chemical-based field control strategies rely on the application of malathion dust. In 1997, a total of 16 699 lbs (7575 kg) a.i. of malathion were applied twice to 62.2 percent of the Californian date groves at a median rate of 2.8 kg a.i./ha (Farrar, 2000).

A5.4 Potential for SIT to control date moth

All available techniques (other than organochloride insecticides, which have been banned in many countries) to control date moth have their specific limitations:

- Parasitoids have limited efficiency due to rearing difficulties, numbers required, dispersal characteristics etc.
- Emballage/ensachage is labour intensive, has the problem of accurate timing, and is not 100 % protective.
- *B.t.* is expensive and inefficient for reasons outlined above.
- Fumigation is applied when damage to the dates has already occurred, and in many countries methyl bromide will not be available in the future.
- Field sanitation requires full support of the growers, is labour intensive, and experience has shown it is not very successful.

However, with careful selection the integration of SIT with several of the above mentioned suppression methods will give much better control than is currently achieved and under some conditions may even result in the eradication of the pest.

A5.4.1 Suitability of date moth to SIT

In 1998, an SIT project on the date moth was initiated with funding by the Secrétariat d'Etat à la Recherche Scientifique et à la Technologie (SERST); this is the only on-going date moth SIT research being carried out anywhere at the present time. Initial work was supported by an FAO/IAEA Coordinated Research Project on F_1 sterility in Lepidoptera, which concluded two years ago. Presently, Tunisia receives support in terms of equipment, training and expert services to develop the SIT technology for date moth under the IAEA Technical Cooperation Project TUN/5/019: *Control of Date Moth using Radiation Sterilization*.

Date moths have been raised under laboratory conditions with maximum production reaching 500 000 adults per week. An artificial diet based primarily on soybean cake and sucrose appears to be a quite successful and cost-efficient means for mass-rearing larvae with comparable developmental characteristics to control groups. The presence of date fruits appears to improve mating significantly.

Research so far has established this preferred diet, established an automatic process for collection of emergent adults and identfied indigenous parasitoids of date moth. Work is on-going regarding mating and oviposition (IAEA, 1999c).

FIG. A5.3. Larva of Ectomyelois ceratoniae.

Photo credit Nadia Al-Khateeb, by permission of the *Arab Scientist*
http://www.arabscientist.org/english/gallery/insects/associate

Results on radiation biology have been variable, so further work is taking place to clarify the appropriate levels for sterilization (Marc Vreysen, pers. comm., 2002). Doses of 200, 250 and 300 Gy applied to 1-2 day pre-emergence female pupae result in egg hatch rates of 71, 63 and 14 percent respectively, compared to a rate of 95 percent in control groups in earlier studies. Results for final preferred radiation levels to achieve the necessary sterility levels without endangering quality will be dependent on confirmation of proper calibration of the irradiation source. The pilot rearing facility in Tunisia has a capacity of as many as 500 000 sterile date moth (both sexes) per week. Field trials in date plantations using this supply have begun.

Lepidoptera species display general radio-resistance, making it difficult to achieve sterility levels reached for other pests (e.g. fruit flies) while maintaining quality. In that respect, the development of SIT strategies employing F1 sterility applied to date moth as well. The overall radiation biology of the date moth remains unclear. In addition, work needs to be done on the behaviour and competitiveness of gamma sterilized date moths in the field. This will be a prerequisite to determine how many moths need to be released per surface unit and hence how big the rearing factory needs to be.

The application of SIT, in combination with insecticide sprays, mating disruption and sanitation, has been shown to give excellent results for another Lepidoptera species, the codling moth in Canada. The available information on damage levels, distribution of the hosts, tractability of the date moth to mass rearing and sterilization all indicate that SIT may prove a valuable addition to IPM of date and other host production areas in the future.

A5.4.2 Probable impacts of SIT against date moth in Tunisia

The only country currently advanced in planning for an SIT-based IPM programme against the date moth is Tunisia. If SIT can be integrated with other control methods against the date moth at the field level, then the problems at the storage level will be significantly reduced. In such a case, SIT-based IPM strategies can be recommended very convincingly. In the broader context, the control or eradication of the date moth would be very likely to result in increases in the profitability of date production, in increased levels of date exports and in the general socio-economic development of the southern region of Tunisia, where much of the dates are grown. Furthermore, the use of SIT would facilitate the development and expansion of dates produced for the international organic food markets, especially those in Europe.

The adoption of SIT-based programmes in Tunisia should not have any significant adverse economic effects on the local economy. There is no reason to believe that the use of SIT strategies will cause any controversies or create any fears among producers. With the prohibition of methyl bromide and with an efficiency level of only 70 percent, under optimum conditions, for *B.t.* applications, the producers should be receptive to SIT-based strategies.

The control or elimination of the date moth at the field level should not facilitate the emergence or increase of other pests. At the packing house level, it may result in the expansion or increase of several species of *Ephestia*, which can develop rapidly. The latter can be treated effectively with methyl bromide; however, since the use of this chemical is soon to be banned, it will be necessary to identify other control strategies if species that are currently secondary pests become more serious (see comments in Section A5.3.1 on heat treatment, CO_2 and phosphine).

A5.4.3 Estimated costs of an SIT programme

In most date producing countries, the large area of alternative hosts also would require treatment if eradication from the date production areas were the ultimate goal. The date plantations in the southern part of Tunisia are perfectly isolated, however, even one oasis from the other. Provided some essential prerequisites are put in place (i.e. the removal of other host trees such as pomegranates and the implementation of good quarantine measures) it is possible that the date moth could be eradicated in southern Tunisia on a sustained basis. Since the entire Mediterranean Basin and the Middle East are infested with the date moth, its eradication in one country will probably be only temporary and re-infestations are very likely to occur unless natural barriers exist, alternative hosts are taken into account and highly effective national quarantine systems are put in place.

Tunisian experts have estimated that for a suppression programme in that country, approximately 2800 million sterile insects per year will be required for date palm alone. Presently there is insufficient information about the required sterile:wild ratio and about the date moth densities to set this figure with certainty. However, using that requirement as an estimate, a three-year SIT programme for the suppression of the date moth at the field level will cost approximately US$4 850 000. In the future, SIT date moth programmes can also target Tunisia’s approximately 25 000 ha of almond and pistachio trees and 14 000 ha of citrus groves that also incur damage.

This cost for production and release of 2800 million sterile date moths per year is calculated on the basis of the following estimates:

Administration	50 000
Rearing unit	2 000 000
Rearing and release equipment	1 565 000
Other equipment	800 000
Staff and logistics	435 000
Total	US$ 4 850 000

These estimates do not appear to include publicity, training, monitoring or expenses for distant transport prior to release. An appropriate radiation source for the sterilization process is already owned by the Tunisian government but is located in Tunis and not in the south of Tunisia – this will be critical to implement an SIT based intervention programme.

Such a programme is the next logical step to small field tests of the research, which is currently under way. There have been a few prior efforts with SIT programmes in Tunisia. In 1974, a technical cooperation project, implemented in collaboration with the United States Department of Agriculture (USDA) conducted some trials with the Medfly. A similar effort against Medfly in conjunction with the IAEA began in 2000 (See Annex 4). These experiences may offer insight into potential pitfalls and lessons learned for SIT in that location.

A5.4.4 Willingness to pay for SIT

Willingness to pay for a "new" technology such as SIT will vary from country to country and industry to industry. It depends on the level of organization of the industry, the main driving force for achieving reduction in damage or replacing other control methods, the availability of funding, market conditions, availability of other effective control methods and other factors (see Annex 6).

In Tunisia, date palms are attacked by several other pests besides the date moth; most notably by other Lepidoptera species of the genus Ephestia, mainly under storage conditions, as well as by the date mite, scales and other secondary pests (Dhouibi et al., 2000). The producers are aware of this damage because the national export promotion agencies collect and share production and yield data. However, the producers feel that pest eradication measures are the responsibility of the government, through its national treatment campaigns, and therefore take no active measures themselves. Indeed, the Tunisian government has developed strong quarantine programmes that have been effective in preventing establishment of the bayoudh disease in dates (Fusarium oxysporum), which devastated date production of the Moroccan fields and some Algerian orchards.

The Tunisian government established a maximum infestation level of 5 percent for the export market. It now faces the task of reducing the current average infestation level of 20 percent to the maximum acceptable rate of 5 percent for exports, while also eliminating all frass and dead larvae from the fruits. Pest control programmes for export crops are essentially funded by the government and have as a goal to improve farmers' income and to increase export earnings. It is expected that these measures will result in improving both the rural and national economies. Since the implementation of an effective quarantine system or of an eradication programme would be quite costly, the present goal of the Tunisian government for date moth is simply to suppress the infestation levels. Because of this historic perspective towards pest control, any initiative towards use of SIT in Tunisia would probably be funded by the government.

A5.4.5 Damage from other pests may delay interest in SIT elsewhere

All date producing areas suffer from more than one pest. For example, California reports the following insect pests on date palms: *Oligonychus pratensis* (the Banks grass mite), the date moth (locally identified as the carob moth), and *Carpophilus* spp./*Heptoncus luteolus* (nitidulid beetles) (Farrar, 2000). The interaction with current pest control methods (e.g. of field applications of *B.t.*, or packing house harvest fumigation) for date moth with other pests of the date palm are highlighted in other sections. Some of these interactions (i.e. control of secondary pests) would be lost with the uptake of SIT, but others are appropriate to use in conjunction with SIT. Some damage may be reduced by the control of date moth as the initial source of boring holes. It appears, however, that some date production industries are so devastated by other pests or plant disease, or by overall low income and opportunity, that the economic motivation for any control of date moth is very low.

Morocco, for example, has approximately 45 000 ha in dates, about 90 percent of which is concentrated in the regions of Ouarzazate and Errachidia. There are approximately 15 different varieties of dates that are cultivated. Total production appears to fluctuate markedly from year to year; in 1997, Morocco produced 110 500 mt; while in 2001, total production decreased to 32 400 mt. Date yields in Morocco are among the lowest in the world.

Moroccan date production suffers from three significant phytosanitary problems. The most severe is caused by *Fusarium oxysporum*. This soil-borne fungus causes a mycosis that eventually kills the tree. Locally, the disease is known as *bayoud*. It is estimated that two-thirds of the date palms in Morocco perished from this pest; this represents a loss of over one million trees. Unfortunately, the best varieties, such as Medjool, are the most susceptible to this disease. *Fusarium oxysporum* represents the principal constraint on expanding date production in Morocco.

The second important pest is *Parlatoria blanchardi*; this is a field pest that in some years causes losses of up to 50 percent of the crop. The Moroccan Institut National de la Recherche Agronomique (INRA) is currently carrying out trials to control this pest with a coccinellid predator. The third pest is the date moth and, as elsewhere, it is treated as primarily a post-harvest problem. In addition to the phytosanitary issues, date production in Morocco is also hampered by erratic rainfall patterns, often punctuated by severe droughts, and the progressive desertification of some of the areas dedicated to date production.

Morocco's date exports are negligible. About 42 percent of the production is destined for self-subsistence, 30 percent is sold in local markets, 20 percent is used as animal feed and the rest is exported. Morocco reportedly exports about 300 mt annually, of which about 60 mt are organic dates. Most of the exported fruit goes to the United Kingdom. At the same time, Morocco imports approximately 1000 mt of dates each year, mostly from Tunisia, Algeria and Iraq. During the 1996-2000 period, the highest recorded yield was 2.6 mt/ha in 1997, while yields in 1999 and 2000 dropped to 1.7 mt/ha. Two parastatal organizations were created in Morocco in the 1970s to improve marketing channels but one of them seems currently to have a very limited role. For these reasons, although Morocco faces important damage from date moth, the country is unlikely to invest in any efforts to control that pest until other phytosanitary problems are resolved.

On the other hand, the Moroccan government currently has a four-pronged research strategy related to date palm:

- the identification and selection of pest resistant varieties;
- the identification and selection of high yielding and high quality varieties;
- the development of effective micro-grafting techniques;

- the propagation of tissue culture, in order to speed the re-establishment of date production areas.

It is estimated that this research strategy will consume about 52 percent of the funds allocated by the government for the development of the national date industry; about 8 percent will be destined for post-harvest treatment. The goal of this programme is to increase export levels to 5000 mt per year by the year 2011. Presumably, this will serve to increase demand for post-harvest treatments. Such a demand may warrant the introduction and use of an SIT-based programme in Morocco by 2010.

A5.5 World production and export of date palms[27]

There are more than 1500 varieties and cultivars of date palms (*Phoenix dactylifera*) grown worldwide; they have different colours, flavours, sweetness, acidity and textures. All major date-producing countries have their own cultivars and favoured varieties, such as Amir Hajj and Ashrashi from Iraq; Saidy and Hayany from Egypt; Deglet Noor and Thoory from Algeria; Ruzeiz, Bukeira, Nebut, Seif and Barhi from Oman (Sanderson, 2001); Medjool from Morocco; and Khalas, Zaghloul, Khuneizi, Hilali, Howaiz, Naghal and Jaberi Fardh, in the United Arab Emirates. As alluded to already, the variety and cultivar of date palm has an important effect on the level of damage from date moth.

World date production has been relatively steady during the last six years (Table A5.1). In 1996, 4.96 million mt were produced while in 2001 world production reached 5.35 million mt. Five countries – Egypt (20.6 percent), Iran (16.8 percent), Saudi Arabia (13.3 percent), Pakistan (10.3 percent) and Iraq (7.5 percent) – accounted for almost 69 percent of the world production in 2001. Iran maintained the highest six-year average production of 893 100 mt. Other countries with averaged production figures between 100 000 mt and 500 000 mt for that period are Algeria, United Arab Emirates, Oman, Sudan, Libya and Tunisia. Countries that appear in international statistics but are not in the top twenty-five producing countries are: Mexico, Gaza Strip (Palestinian Territories), Jordan, Djibouti, Benin, Kenya, Cameroon and Peru.

The total world area dedicated to date production (Table A5.2) has increased from 876 596 ha in 1996 to 945 762 ha in 2001; this represents an 8 percent increase in area. The largest area devoted to dates in 2001 was 180 000 ha in Iran. Iran, Saudi Arabia, Algeria and Iraq, together account for nearly 59 percent of the total area planted with dates in 2001 according to FAO statistics. The higher production is not always tied to the largest production area, however, most notably in the case of Egypt where much higher yields have been achieved over the six years presented (Table A5.3).

Average production yields[28] in the past six years have ranged from the low of 7.1 mt/ha in 1997 to 8 mt/ha in 2001. However, there are very significant differences in yield among the countries. Three countries – Egypt, China and Bahrain – have reported yields over 20 mt/ha. In 1996, Egypt obtained an average yield of 27 mt/ha while in 2001 it was 34.48 mt/ha, by far, the highest yield recorded that year. China's yields show an impressive evolution, from a low of 5.4 mt/ha in 1997 it had reached 20.8 mt/ha in 2000, second only to Egypt. The yields

[27] All statistics are from the Food and Agriculture Organization of the United Nations (FAO), FAOSTATS, and refer to both fresh and dried dates combined. Data may be updated each year by visiting www.fao.org, databases, primary crops.

[28] Not all statistics match with the calculation of dividing the recorded production level by the area for each country. For a discussion of the quality of data, see www.fao.org.

for most other countries are consistently below 10 mt/ha. In 2001, according to FAO statistics, 11 of the top 25 producing countries had yields of 5 mt/ha or less.

Table A5.1. Date production (1000 mt) in the leading 25 countries from 1996-2001 (in descending order by six-year average production)

Country	2001	2000	1999	1998	1997	1996	Six-year average
1. Islamic Republic of Iran (Iran)	900	900	908.3	918.1	876.5	855.5	893.1
2. Egypt	1 102.4	1006.7	906.0	839.8	740.8	738.1	889
3. Saudi Arabia	712	712	712	648	649.2	616.9	675
4. Pakistan	550	550	579.9	721.6	537.5	534.4	578.9
5. Iraq	400	400	438	630	625	797.5	548.4
6. Algeria	370	365.6	427.6	387.3	303	360.6	369
7. United Arab Emirates (UAE)	318	318	305	290.4	288.2	244.6	294.0
8. Oman	260	260	282	236	185	185	234.7
9. Sudan	177	176	175.5	175	174	167.5	174.2
10. Libyan Arab Jamahiriya (Libya)	132.5	132.5	132	130	128.1	125	130
11. Tunisia	107	105	118.8	103.0	95	74	100.5
12. China	110	125	115	89	38	68	90.8
13. Morocco	32.4	74	72.6	85	110.5	80	75.8
14. Yemen	29.8	29.8	28.5	26.9	26.2	24.2	27.6
15. Mauritania	22	22	20	13	35.8	20.1	22.15
16. United States of America (USA)	15.9	13.6	20.2	22.5	22.6	20.9	19.3
17. Chad	18	18	18	18	18	18	18
18. Qatar	16.5	16.1	16.4	16.4	22.9	14.6	17.15
19. Bahrain	16.5	16.5	16.8	16.6	16.5	16.5	16.6
20. Israel	9.5	11.7	10.9	8.2	9.8	10.8	10.15
21. Somalia	10	10	9.5	9.4	9.5	9.5	9.7
22. Turkey	9.4	9.4	9.4	9.3	10	9.4	9.5
23. Kuwait	10.4	10.2	7.9	6.5	6.7	5.0	7.8
24. Niger	7.6	7.6	7.6	7.6	7.6	7.6	7.6
25. Spain	7	7	7	7.5	8	8.1	7.4
World total (1000 mt) including countries not shown here	**5 353.1**	**5 190.1**	**5 189.6**	**5 324.1**	**4 902.8**	**4 969.3**	**5 154.8** 6-yr avg of world total

Export statistics appear less reliable, probably due to reports of re-export from non-producing countries (e.g. France shows exports of 9576 mt in 2000 but no production). The total world exports were reported as 545 513 mt in 2000, the year that production was 5 190 100 mt. The major exporters were the United Arab Emirates, which exported 189 200 mt; Iran with 101 100 mt; and Pakistan with 48 600 mt. Many of the date producing countries also import supplies. Other sources of data for the volume and value of national exports of date should be consulted when considering the potential market for date moth SIT.

About 90 percent of the crop is sold to the commercial sector. Approximately 65 percent is sold in local markets, around 1 percent is sold to the food retail sector, and about 29 percent is exported. The other 5 percent is withheld from the market; some for domestic consumption and some are stored from March until August, when they are exported. It is estimated that less than 10 percent of the crop is processed into paste.

Table A5.2. Area under date production (ha) 1996-2001
(in descending order by six-year average production)

Country	2001	2000	1999	1998	1997	1996
1. Iran	180 000	180 000	177 272	176 908	192 254	166 133
2. Egypt	32 000	28 982	31 976	29 000	28 000	27 296
3. Saudi Arabia	141 131	141 131	141 131	106 460	106 137	100 858
4. Pakistan	75 000	75 000	76 900	75 500	75 100	74 559
5. Iraq	135 000	135 000	145 000	144 000	156 000	176 000
6. Algeria	100 000	100 120	100 120	97 990	96 520	96 560
7. UAE	62 000	62 000	60 000	59 179	37 000	31 005
8. Oman	36 000	36 000	35 500	35 500	30 000	29 500
9. Sudan	19 500	19 000	18 500	18 200	18 000	18 000
10. Libya	26 500	26 500	26 200	26 000	25 000	24 000
11. Tunisia	30 000	30 000	30 000	30 000	27 000	29 480
12. China	6 000	6 000	6 000	5 000	7 000	6 800
13. Morocco	46 650	46 650	44 472	44 200	42 000	44 400
14. Yemen	22 755	22 755	22 162	20 627	20 144	19 354
15. Mauritania	8 000	8 000	8 000	5 000	12 000	8 000
16. USA	1 820	1 900	1 980	1 980	1 940	1 890
17. Chad	7 600	7 600	7 600	7 600	7 600	7 600
18. Qatar	1 400	1 400	1 366	1 368	2 567	1 897
19. Bahrain	823	823	830	825	823	823
20. Israel	1 300	1 330	1 301	1 260	1 240	1 310
21. Somalia	2 400	2 400	2 300	2 300	2 300	2 300
22. Turkey	3 850	3 850	3 850	3 850	3 850	3 570
23. Kuwait	1 350	1 350	1 050	870	890	670
24. Niger	2 200	2 200	2 200	2 200	2 200	2 200
25. Spain	500	500	500	585	588	494
Total (ha)	**945 762**	**942 675**	**950 166**	**898 635**	**898 170**	**876 596**

The government basically sets prices and thus there are no large price fluctuations. The current farm gate prices are US$3/kg for first quality fruit, US$2.50/kg for second quality, and US$2/kg for third quality. Tunisia exports about 29 percent of its date crop, approximately 29 000 mt annually, earning approximately US$70 million each year. Dates represent the third most important Tunisian export. Presently, there are 43 companies that export dates and there is a very high level (80 percent) of public sector participation in them. Most of Tunisian dates are exported to the EU, to other European countries, and to some Far Eastern countries.

A5.5.1 Date production in Saudi Arabia

Saudi Arabia is a major producer of dates, most of which are locally consumed. There appear to be several local types of pests that attack dates. Since 1995, a new bacterial disease (*Erwinia chrysanthemi*) has been detected in the Al-Quassim region of the country; some varieties (Succary) have proved to be very susceptible to this disease while others (Roshody and Helwa) have proved resistant to the infection (Abdalla *et al.*, 2000; EPPO, 2000; EPPO, 2001).

Table A5.3. Date yields (mt/ha) 1996-2001
(in descending order by six-year average production)

Country	2001	2000	1999	1998	1997	1996
1. Iran	5.0	5.0	5.1	5.2	4.6	5.2
2. Egypt	34.5	34.7	28.3	29	26.5	27
3. Saudi Arabia	5.1	5.1	5.1	6.1	6.1	6.1
4. Pakistan	7.3	7.3	7.5	9.6	7.2	7.2
5. Iraq	3	3	3	4.4	4.0	4.5
6. Algeria	3.7	3.7	4.3	4.0	3.1	3.7
7. UAE	5.1	5.1	5.1	4.9	7.8	7.9
8. Oman	7.2	7.2	7.9	6.7	6.2	6.1
9. Sudan	9.1	9.3	9.5	9.6	9.7	9.3
10. Libya	5.0	5.0	5.0	5.0	5.1	5.2
11. Tunisia	3.6	3.5	4	3.4	3.5	2.5
12. China	18.3	20.8	19.2	17.8	5.4	10
13. Morocco	7	1.6	1.6	1.9	2.6	1.8
14. Yemen	1.3	1.3	1.3	1.3	1.3	1.3
15. Mauritania	2.8	2.7	2.5	2.6	3	2.5
16. USA	8.7	7.2	10.2	11.4	11.6	11
17. Chad	2.4	2.4	2.4	2.4	2.4	2.4
18. Qatar	11.8	12	12	12	8.9	7.7
19. Bahrain	20.1	20.1	20.2	20.1	20.1	20.1
20. Israel	7.3	8.8	8.4	6.5	7.8	8.3
21. Somalia	4.2	4.2	4.1	4.1	4.1	4.1
22. Turkey	2.4	2.4	2.4	2.4	2.6	2.6
23. Kuwait	7.7	7.5	7.5	7.5	7.5	7.5
24. Niger	3.5	3.5	3.5	3.5	3.5	3.5
25. Spain	14	14	14	12.8	13.7	16.4
Total	**8**	**7.9**	**7.8**	**7.8**	**7.1**	**7.4**

FAO yield statistics converted here to mt/ha.

A5.5.2 Date production in the United Arab Emirates

The United Arab Emirates are one of the most important dates producers; in 2000, they produced approximately 318 000 mt (about 6 percent of the world's crop) on 62 000 ha (resulting in an average yield of 5.1 mt/ha). The United Arab Emirates are the largest exporters of dates. In 1999, they produced 305 000 mt and exported approximately 189 200 mt (about 42 percent of the global date export market of that year); thus, they exported about 62 percent of their annual production.

The Abu Dhabi Emirate is by far the largest producer of dates in the United Arab Emirates; there are said to be approximately 16 million date palms in this Emirate. There are approximately 4 million palms in the other six Emirates. However, of Abu Dhabi's 16 million palms, only 6 million are currently producing, the rest are young date palms growing on many hundreds of new farms; these palms will not produce significant crops for another three to five years. When they do, the United Arab Emirate's date production could match that of Saudi Arabia.

A very high number of the producing date palms is found in the various oases of the Al Ain region, there is a total of 1.108 million producing palms in this region. The Al Ain Oasis has 60 000 date palms and the Al Jimmi/Qattara Oasis has about 103 000. Within the streets of Al Ain, there are approximately 25 000 date palms, all of which are harvested and thus contribute to the overall regional crop. Additionally, there are new farms that are being added in places like Mubazzarah, where the palms will not come into significant production until 2005. At that time, the Al Ain region may produce four to five times what it does now.

Date-producing oases in the United Arab Emirates are made up principally of female palms, which are the ones that bear fruit. The plantations space the palms approximately 8 m apart, which means there are almost 150 palms per hectare. Usually, there is one male date palm for every 30 or 40 female palms. Some oases are now being planted without any male plants and high quality pollen is imported. Even now, it is not uncommon for growers to select spathes of male pollen from the market.

The spathes containing pollen appear in February/March and last until early April. Since natural pollination depends on wind and insect vectors and since these means result in very low levels of fertilization, certainly insufficient for commercial production, growers engage in artificial pollination, both by hand and by the use of mechanical blowers.

A5.5.3 Date production in the Gaza Strip

There are very few available data on date production and export in the Gaza Strip. In 1999, the Gaza Strip produced about 2700 mt and about 300 mt were exported; this level of exports represents about 11 percent of total production and had a market value of US$90 000. The market value of date exports from the Gaza Strip remained unchanged from 1995 to 1999.

A5.5.4 Date production in the United States of America

Date production in the USA dates from the 1700s. Although the original palm trees descended from varieties brought from Mexico, which in turn had been brought from Spain, the current varieties were imported directly from Saudi Arabia. California produces primarily two date varieties. About 75 percent of the crop is made up of the Deglet Noor variety, which was introduced in the 1900s, while most of the rest of the crop consists of Medjool, a more valuable variety.

Optimal production density is considered to be about 119 palm trees per hectare. Under Californian conditions, date palms attain full production in 10-13 years. They are harvested from late August until mid-December. Since dates ripen unevenly, the high-value Medjools are harvested repeatedly, while the Deglet Noor trees are harvested only once, when the majority of the dates are ripe.

In 2000, the USA produced about 22 000 mt of dates on approximately 8000 ha (resulting in an average yield of 2.8 mt/ha). Almost the entire US production is based in California, especially in the Coachella Valley. In 1996, California’s date crop was valued at US$18.5 million dollars. Almost none of the US production is exported.

A5.6 Conclusions

The date moth (*Ectomyelois ceratoniae* Zeller) is a serious pest of date palms and is well documented throughout the Mediterranean Basin and the Middle East. Although distribution is not confirmed, the species appears to be established in Europe across Russia, the Indian Subcontinent, parts of North and South America, the Caribbean and parts of Africa. Damage from date moth increases during storage of dates, leading many countries to fumigate post-harvest. Pomegranate, pistachio, carob, citrus, almond and walnuts are other important commercial hosts of the date moth. Non-commercial hosts include acacias and *Retama retam*.

The date moth meets biological and technological criteria for a species to be suitable for control by SIT, although improvements are needed and research is on-going. Information on the socio-economic and environmental impact criteria remain limited. The most extensive information is presented for Tunisia, where research on the date moth is well advanced. Motivations for applying SIT to date moth in Tunisia include:

- upcoming restriction of methyl bromide as a fumigant;
- farmer resistance to field application of pesticides;
- limited efficacy of *B.t.;*
- compatibility of SIT with other biological control agents;
- better prices for higher quality dates;
- existing export markets and opportunities for larger markets for organic production;
- national development goals for the date growing regions.

Challenges to a date moth SIT programme in Tunisia will include:

- massive increase in production of sterile date moth;
- change to the application of *B.t.* and the control of secondary pests;
- farmer expectation that government pays all costs for control;
- infestation of neighbouring countries;
- competition from increasing production in the UAE, Morocco, etc. in the mid-term market;
- any remaining difficulties with SIT for this species.

While Tunisia is the obvious location for these first field trials, date moth attacks date palms and other commercial crops in many countries. A successful demonstration of date moth SIT in Tunisia could lead to a rapid increase in demand for sterile date moth as the concerns for pesticide use and the restrictions on residues and fumigants increase.

A5.7 References

References in individual Annexes may have “a”, “b” etc. following the publication date, this refers to the way they appear in Section 9.1 Bibliography where all references are listed.

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Other useful resources

***For updates on quarantine pests of Europe:* www.eppo.org**

***Date palm diseases*: http://www.scisoc.org/ismpmi/common/names/datepalm.htm**

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A5.8 Appendix. Market questionnaire applied to date moth for one country (Tunisia)

The original market questionnaire to collect information required to do a Model Business Plan for SIT appears in Annex 6.

MARKET QUESTIONS FOR IAEA REPORT- Date moth

June 29, 2001

Dr DHOUIBI Mohamed Habib: dhouibi.med@inat.agrinet.tn

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Species to be controlled (scientific name and common name)

Date moth or Carob moth: Ectomyelois ceratoniae

Country or region where study undertaken

Mediterranean areas and Middle East

List of main hosts and alternative (or less preferred) hosts if known: *It is a polyphagous, frugivorous species*

Commercial: *Dates, Pomegranates, Pistachios, Almonds, Oranges, and Carobs.*

Wild*:* Retama retam, Acacia

OR is the species to be controlled a threat to public health? animal health?

Information on impact to human health or animal health*: No human and animal health impact*

Seasonal variables

Any known impacts of climate, seasonal changes etc. on a) insect population, b) insect damage, c) availability of hosts (either commercial or wild)?

Attach records on seasonal variation (e.g. rain and/or temperature, whatever is causing the impact).

It is a desert pest, its development occurs in the south of the North African countries and in the Middle East areas, so the maximum development occurs in spring and in summer seasons when the temperature is more or less 30°C and relative humidity 50% ± 5%; but when the temperature is high, more than 35°C (July, August), it becomes lethal for the pest, and development is stopped or decreased when the temperature decreased.

Pest population level and damage

- Data on trap catches – Or – impact in terms of animal health (anecdotal or quantified)

Estimation of potential damage/area or per head of livestock (based on literature or questionnaires).

Damage is related to the type of host plants. For example pomegranate, all Tunisian varieties: 90% of infestation in the south but only 15% in the North, in Iraq where the species is an important pest on pomegranate the damage is around 45%, on dates 18 to 20% in Tunisia, 30% in Algeria, and more than 40% in stored and packing houses in Tunisia, Algeria and Libya. On pistachios, the infestation reaches 75% (Tunisia).

Has the population or damage varied over recent years? If so, why?

Yes it depends on the climate: Dry seasons or periods are the best periods for high infestations.

Infestations are bigger in the south of the Mediterranean countries compared to the North of the same area.

What are the other primary pests of this crop? (Or other diseases of humans or animals)

There are several other pests of the palm date crop, mainly other Lepidopteran species of the genus Ephestia *(infestation occurs mainly in storage), scales, mites (one species the date mite) and other secondary pests.*

Are growers aware of the percentage of damage from the target species versus from other sources? What are these percentages?

Yes, Products and yields are controlled by exportation services, so growers are aware of the damage, but they do not care about that because, it is the government who does the job and it is considered the main responsible (national treatment campaigns). The acceptable level at exportation is 5% of infestation and to enhance the exportation, the government has to decrease the dates' infestation level from 20 to 5% in field, without letting frasses and dead larvae in fruits.

Origin of introduction

Is the year, pathway and country of origin for the introduction of this species known?

No, the infestation is an old problem ,we talk about dates infestation since 1800 and the origin is not well known

Reintroduction

If this species were eradicated or suppressed, is it likely that new introductions will occur that sustain the population? e.g. are neighbouring areas infested?

The Mediterranean area is infested but no eradication programme was done and only a national suppression programme is made in certain countries. But to avoid this, it is necessary to have a serious (perfect) quarantine system in each country, So new infestations are possible in these conditions.

How competent and funded are the domestic quarantine services in general?

They are weaker in the majority of the countries. In Tunisia it is better and serious according to the local serious quarantine system against the date bayoudh disease (Fusarium oxyxporum), which devastated the Morocco oasis and some of the Algerian orchards, so the Tunisian government has developed a strong quarantine system to avoid the introduction of this fungus from our neighbouring Algeria.

Would the goal be eradication or suppression?

According to the cost of the treatment, our aim is only the suppression for the moment. And a strong quarantine system can be expensive.

Level of organisation of the industry

- Livestock organisations or growers groups (number and resources),

In Tunisia, 43 export companies

- Level of state intervention: *80%*

- Level of development of industry: *20%*
- Infrastructure status (transport facilities, etc.): *90% state interventions*

Are these products aimed at export? If so for which markets?

Yes, most of the products, to European countries, CEE, and certain east countries

Anticipated source of payment for SIT for this pest.

Only in Tunisia an anticipated program for experimental purpose financed by Research ministry since 1998 (SERST in Tunisia), and recently TCP project with IAEA for a pilot project.

Any other examples of SIT use?

In Tunisia the first trial was made on 1974 on Medfly, it was a Technical Cooperation Project between USDA and Tunisian Government. Recently a TCP project with IAEA for a pilot project started since 2000. For date moth, the SIT project started on 1998 and financed by the Ministry of Research

Examples of government vs. private funding for pest control programs?

100% Government funding for exported crops

What is the driving force for the eradication or suppression? Who is most interested?

Improvement of farmer's income and exportation level. All are interested.

What interests (economic, political, social) would be impacted by a successful SIT program?

The main impacts are economic and socially by improvement of farmers income and country income.

Areas and Production variables

- Land surface (ha) affected – geographic description of areas if SIT will be a zonal approach, with some areas being treated before others:
  - *27 000 Ha of date palm trees in the south in Tunisia and more or less 96 000 ha in Algeria (this area must be treated before)*
  - *Other crops: 25 000 ha almonds and pistachios, 14 000 ha of Citrus*
- % of area under high/low input : for dates

High input: 85 % of the area

Low input: 15 % of the area

- Yields under high/low input

High input: 200Kg/tree

Low input: 30 Kg/tree

- Any information on costs for high versus low input, and what each consists of (by area if practices vary).

High input: Good quality: 3 US$

Low input: worse quality: 0.5 US$

- Estimates of unrecorded production (not covered in numbers above)

In General all the production is recorded, but not yet for local families consumption

Market variables for dates

Market categories (local market, co-operative, supermarkets, export)

Sold quantities: Local market: 65%, supermarkets: 1%, export 29%,

Percentage of production that remains outside of any markets (subsistence)

5% of dates are stored from March till August of each year to be exported next year early. But the family farmers use other quantities not known or weighted. It can be known or evaluated by several surveys.

Other products/uses of the livestock that may not be quantified

Less than 10% of the total yields are transformed in " pate"

Evolution of prices/month (e.g. for cattle or for fruit)

There is no big variation in the process of dates, because the government determines each year the low unit price. The high quality of dates are paid with high prices (ex: 3 US$/kg)

If markets exist:

Farm gate price (US $/kg) per market category

First quality: 3 US$/kg

Second quality: 2.5 US$/kg

Third quality: 2 US$/kg

Volumes being sold to each market category (head or mt)

It depends on the year: in good year: we get good quality: 110 000T. In the worse case (bad year) 30% of the production: good quality and 70% low quality.

Volumes being sold for industry/fresh

90% of the total production sold to the industry (29% exported)

Imports and exports of similar commodities (mt) (i.e. what an improved production might mean in terms of less imports)

Imports of dates: 0, exports of dates 29 000T/year

Present export markets (% change and amounts by country)

Dates are exported to several European countries, the whole amount per year is 70 to 75 millions US$

Potential market gain (domestic and export)

Dates represent the third potential export market for the country.

Is there an existing market for better quality or residue free products? What other factors influence the destination of the product?

There are Bio dates (500 T dates in 2001). The other factors are the use of chemical treatments, and level of infestation

What is the cost differential?

Bio dates: 6 US$

Normal dates: 3 US$

Current control costs

What control methods are commonly used? (note if varies by country/area)

Use of only bio product for treatment (Bacillus thuringiensis), 3 times/year by aircraft, and methyl bromide in the packinghouses (43 stations).

Costs of these control methods

Air craft: 15US$/ha

Bio product: *20 US$/ha*

It is difficult to evaluate the last operation because the fees of the fumigation unit is very expensive: 150 000 US$ and the methyl bromide chemical is 300 US$: 50Kg; the treatment is made by 85g/T during 3 hours.

Which pesticides are used?

Bacillus thuringiensis in the field and methyl bromide in the packinghouses (post harvest)

Are there any expected changes in the availability and/or registration of these pesticides over the next 5 years? 10 years?

Yes, There will be a serious change toward the biological control with parasitoids and SIT programs according to the limited efficiency of the Bacillus thuringiensis and the soon interdiction of methyl bromide

What other pests are also controlled by these pesticides?

All the related species of the Ephestia genus in the field and all the species of Lepidoptera and Coleoptera in packinghouses

How much of the area is covered with pesticides? (or head of cattle if something applied to the animal)

In this moment to protect fruits, 50% of the grown area uses this BT method. The other 50% of the grown area is treated with other methods (use of plastic bags, nets and other kind of papers etc…)

Are contractors used for pesticide applications? (if so, what are typical costs? and who bears the costs?)

Yes there are two contractors for pesticide applications and only one working under the Agricultural ministry authority and it is OK. Costs are 15 US$/ha. The government bears the costs, the farmer will be charged after.

What is the cost of aerial spraying? (examples of other projects that use this)

15 US$/ha, 3 times /year, treated area 14 000 ha

What is the cost of ground pesticide application

Hours of labour/ha

Pesticide cost/l

Litres of pesticide/ha

Machinery/hour

Hours of machinery

Machinery driver/hour

Hours of driver/ha

no applications/intensive production

no application/less intensive or subsistence production

In spite of its efficiency, the ground treatment is estimated costly by the government and it is not used in oasis. The farmer prefers aircraft treatment for following reason:

- *Less costly*
- *Rapid, in our situation the treatment must be done for all the area (14 000) during a short period of 10 days.*
- *And can reach all the geographic area(littoral oasis, mountain oasis ...)*

- % residual losses/high intensity production*: less than 4%*
- % residual losses/low intensity production: *superior to 20%*

(residual means damage that still occurs even when currently available treatments are applied or management practices are implemented)

Not evaluated but it is easy to do by surveys

- Indirect damage (quarantine restrictions & environmental impact)

If treatment in post harvest is not achieved, losses can reach 40% rapidly. So it is recommended imperatively to treat all yield after harvest (by fumigation using methyl bromide…. And other methods…)

Is the pesticidal treatment used for this species also impacting other species? (beneficial or damaging)

In the field the Bt *treatment efficiency is limited to 70% but in post harvest the fumigation is very efficient (100%) for all the species, but it becomes a prohibited chemical (methyl bromide).*

If this species is eradicated or controlled, what other pest is likely to expand range or increase in population?

This situation can occur only in the stored products where several species of Ephestia can develop rapidly

If the above occurs, what control methods will be used for that pest?

Till now, Methyl bromide is used. It will be prohibited soon; so we have to find an alternative or an other fumigant.

What will be the likely result of the removal of the target species? (e.g. expansion production, change in socio-economics of area, land ownership, health issues, etc)

Increase of farmer revenue, improvement of social situation, improvement of exportation, development of the south area of the country etc…

What are the other bottlenecks to expansion? What specific markets will be opened by the elimination of the pest? by the reduction of pesticide residues?

Market of bio products everywhere in the world.

Are there any clear (particularly local-owned) competitors to SIT that would oppose the use of this technology?

In our case there will be only the sellers of BT product formulations (two sellers of this product in the country).

What are the growers and the consumer attitudes towards pesticide use in the country or region?

The growers refuse totally the chemical treatments because they had bad experiences with chemical eradication of Locusts.

Any data on pesticide impact on human health in the area? particular problem with worker safety, storage, disposal or other problems with pesticides?

There is no human or health problem in our case (Tunisia) because we are using only the BT product, which are considered as bio pesticides.

Any reason to expect aerial release of sterile insects may be controversial (e.g. fear of planes flying over, belief that sterile flies are radioactive, or other myths)?

For the moment, there is no reason or fear problem, because the efficiency of Bacillus thuringiensis treatment is around 70% in good application conditions according to the behaviour of the insect (development inside the fruit) and the prohibition of methyl bromide.

OTHER COMMENTS

Anything else you heard that could impact the size and stability of the market or ability to pay?

The best solution is the following:

-Resolve the problems when the products are in field area (oasis) and no more. In this case the SIT is highly recommended. As a consequence, there will not be problems in storage area for the yields.

SIT variables: The costs are given for SIT project during 3 years

Unit costs of infrastructure, equipment and materials for the SIT project

SIT: Total cost **4.850 000 US$**

Administration	% Of total costs: 1% (**50 000 US$)**
Publicity	SIT publicity/farm $: **15 000 US$ during 3 years**
Training	SIT training cost/supervisor **60 000 US$ for all area** SIT supervisors/ha: **120 000 US$ for all area**
Monitoring	Trap cost $/trap inc service: **90 000 US$ during 3 years** SIT monitoring traps/ha: **4 traps**
Fly collection	Transporter to field $: Operating/yr**: 9 months** Driver/million flies:

Ground releases	Distributing van $
	Operating/yr
	Technician/ha
	Technician/month
Air releases	Costs of air releases/ha
	No airplanes/ha
Release center	Cost of construction
	Cost of operation

Project budget plan: Total cost: 4 850 000 US $

Rearing unit construction: 2 000 000 US $

Equipment (diet and small equipments): 800 000 US $

Rearing equipment and release equipment 1 565 000 US $

Staff and logistic 435 000 US $

Administration 50 000 US $

How many sterile insects would be needed per year, for how many years, to complete an eradication project?

Or how many would be released for suppression or as a prophylactic?

We are planning for suppression and in our program 2800 millions of sterile insects are needed per year.

Annex 6
Market issues

Market questionnaire for potential SIT programmes

Species to be controlled (scientific name and common name)

Is this species already controlled using SIT?
If not, what is the status of research? (See Section 4.1 on suitability of species)

Country or region where market study is undertaken

List of main hosts and alternative (or less preferred) hosts if known
Commercial
Wild
OR Is the species to be controlled a threat to public health? animal health?
Information on impact to human health or animal health.

Seasonal variables
Any known impacts of climate, seasonal changes etc on a) insect population, b) insect damage, c) availability of hosts (either commercial or wild)?
Attach records on seasonal variation (e.g. rain and/or temperature, whatever is causing the impact)

Pest population level and damage
(Plant pests) Data on trap catches and/or damage to crop(s)
OR (Animal pests) Impact in terms of animal health (anecdotal or quantified),
Estimation of potential damage/area or per head of livestock (based on literature or questionnaires)

Has the population or damage varied over recent years? If so, why?

What are the other primary pests of this crop? (or other diseases of humans or animals)

Are growers aware of the percentage of damage from the target species versus from other sources and what are these percentages?

Origin of introduction
Is the year, pathway and country of origin for the introduction of this species known?

Reintroduction
If this species were eradicated or suppressed, is it likely that new introductions will occur that sustain the population? e.g. are neighbouring areas infested?

How competent and funded are the domestic quarantine services in general?

Would the goal be eradication or suppression?

Level of organization of the industry

- Livestock organizations or growers groups (number and resources)
- Level of state intervention
- Level of development of industry
- Infrastructure status (transport facilities, etc)

Are these products aimed at export? If so, for which markets?

Anticipated source of payment for SIT for this pest

Any other examples of SIT use in this area or country?

Examples of government vs. private funding for pest control programmes?

What is the driving force for the eradication or suppression? Who is most interested?

What interests (economic, political, social) would be impacted by a successful SIT programme?

Areas and production variables

- Land surface (ha) affected – geographic description of areas if SIT will be a zonal approach, with some areas being treated before others
- Percentage of area under high/low input
- Area under IPM, organic, other quality protocols
- Yields under high/low input
- Any information on costs for high versus low input, and what each consists of (by area if practices vary)
- Estimates of unrecorded production (not covered in numbers above)

Market variables

Market categories (local market, co-operative, supermarkets, export)

Percentage of production that remains outside of any markets (subsistence)
Other products/uses of the livestock that may not be quantified

Evolution of prices/month (e.g. for cattle or for fruit)

If markets exist

Farm gate price (US $/kg) per market category

Volumes being sold to each market category (head or mt)

Volumes being sold for industry/fresh

Imports and exports of similar commodities (mt) (i.e. what an improved production might mean in terms of less imports)

Present export markets (percentage change and amounts by country)

Potential market gain (domestic and export)

Is there an existing market for better quality or residue free products? What other factors influence the destination of the product?

What is the cost differential?

Current control costs
What control methods are commonly used? (note if varies by country/area)

Costs of these control methods

Which pesticides are used?

How much of the area is covered with pesticides? (or head of cattle if something applied to the animal)

Estimate percentage of the area treated with each active ingredient and number of applications (distinguish between conventional (high, low) /IPM/other)

Product concentration (% ai) and application rate (or product commercial name)

Is there any expected change in the availability and/or registration of these pesticides over the next 5 years? 10 years?

What other pests are also controlled by these pesticides?

Are contractors used for pesticide applications? (If so, what are typical costs? and who bears the costs?)

What is the cost of aerial spraying? (examples of other projects that use this)

What is the cost of ground pesticide application?

Hours of labour/ha
Pesticide cost/l
Litres of pesticide/ha
Machinery/hour
Hours of machinery
Machinery driver/hour
Hours of driver/ha
No. applications/intensive production
No. application/less intensive or subsistence production

- Percentage residual losses/high intensity production
- Percentage residual losses/low intensity production

(Residual means damage that still occurs even when currently available treatments are applied or management practices are implemented.)

- Indirect damage (quarantine restrictions & environmental impact)

Is the pesticidal treatment used for this species also impacting other species? (beneficial or damaging)

If this species is eradicated or controlled, what other pest is likely to expand range or increase in population?

If the above occurs, what control methods will be used for that pest?

What will be the likely result of the removal of the target species? (e.g. expansion production, change in socio-economics of area, land ownership, health issues, etc.)

What are the other bottle necks to expansion? What specific markets will be opened by the elimination of the pest? By the reduction of pesticide residues?

Are there any clear (particularly local-owned) competitors to SIT that would oppose the use of this technology?

What are the growers and the consumer attitudes towards pesticide use in the country or region?

Any data on pesticide impact on human health in the area? Any particular problems with worker safety, storage and disposal or other problems with pesticides?

Any reason to expect aerial release of sterile insects may be controversial (e.g. fear of planes flying over, belief that sterile flies are radioactive, or other myths)?

SIT variables

Unit costs of infrastructure, equipment and materials for the SIT project:

Administration	% of total costs
Publicity	SIT publicity/farm $
Training	SIT training cost/supervisor $ SIT supervisors/ha
Monitoring	Trap cost $/trap (including servicing) Monitoring traps/ha (predicted frequency of servicing)
Local transport	Capital cost of vehicle(s) for transport from source to field $ Operating cost of vehicle(s)/yr Labor cost for drivers
Ground releases	Capital cost of distribution van(s) $ Operating cost of vehicles/yr Technicians/month
Air releases	Costs of air releases/ha Number of airplanes for area/frequency of release
Release center	Cost of construction Cost of operation

Sterile insects required for release
Is male only sterile insect supply available for the target species?

What is the estimated ratio of sterile:wild recommended for this species?

How many sterile insects would be needed per year, for how many years, to complete an eradication project?

OR how many would be released for suppression or as a preventative release?

OTHER COMMENTS
Anything else you heard that could impact the size and stability of the market or ability to pay?

Annex 7
Production facilities and processes

A7.1 Production facilities: example floor plans

Example floor plans for two sterile fruit fly production facilities appear in this annex. The first, a melon fly facility in Japan pictured here, is unusual in that it is multi-storey and features a high level of automation (see Section 5.1).

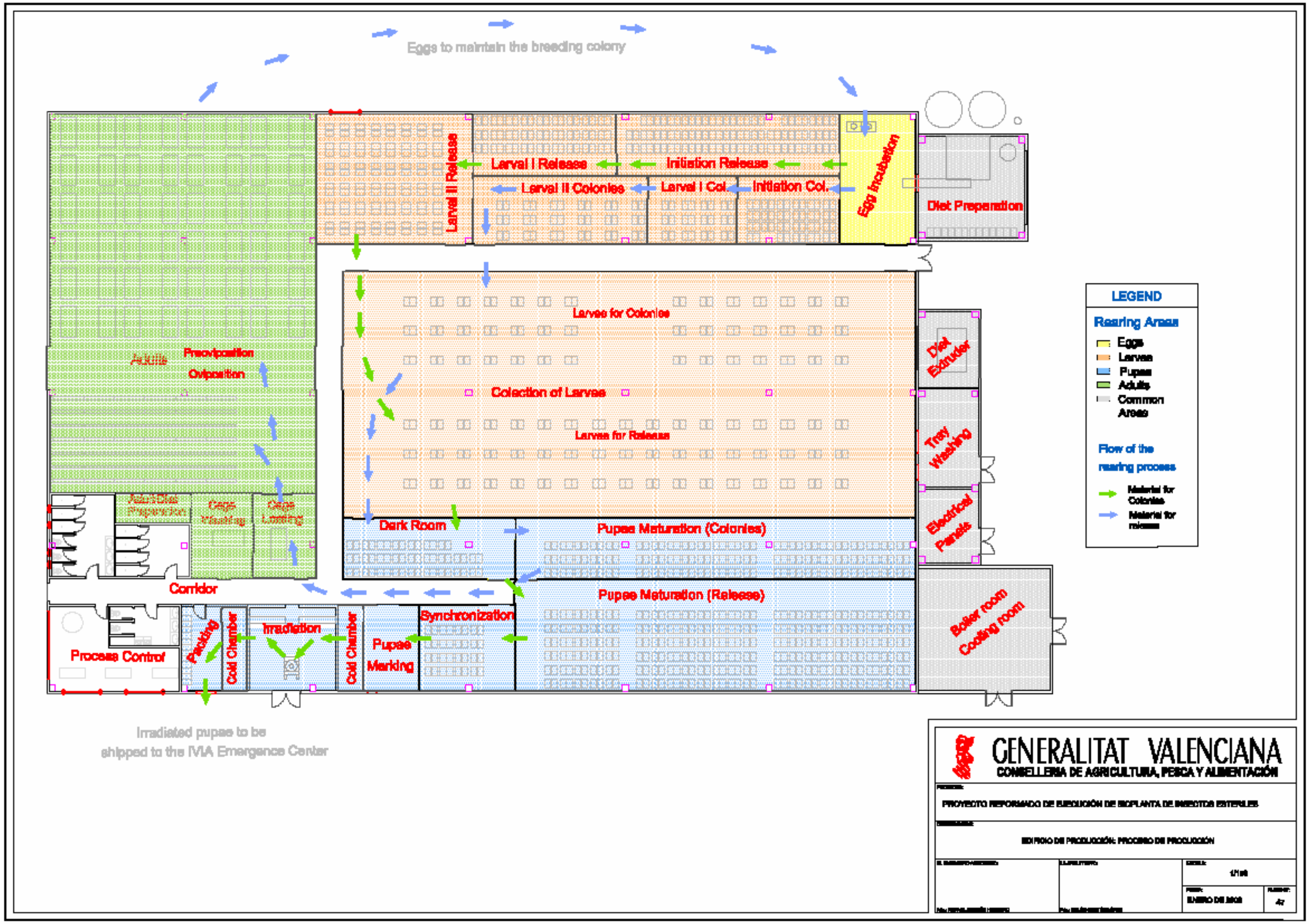
Aerial view of the melon fruit fly production facility in Okinawa Prefecture, Japan
(Source: Bakri, A. 2001, Slide show #16 on IDIDAS Web site)

The second example, the Medfly facility in Spain, was only recently constructed and is the much more typical single storey structure. Both feature distinct areas for each step of the production process. The Valencia, Spain, facility floor plans include arrows showing the flow of the process from one segregated area to the next.

These figures appear in the following two pages.

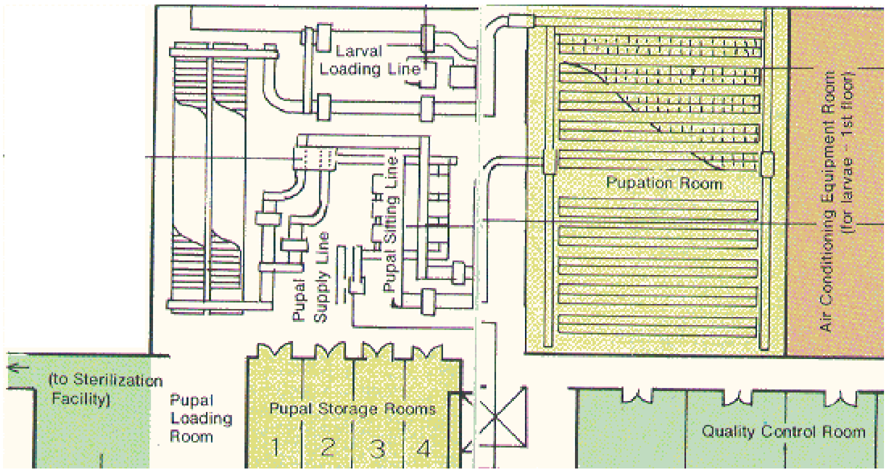
A7.2 Production processes

Flow charts of the entire process from rearing through to release appear after the floor plans. There is a final schematic of the overall process control, including quality control of inputs as well as the internal processes.



Ground floor

Upper floor

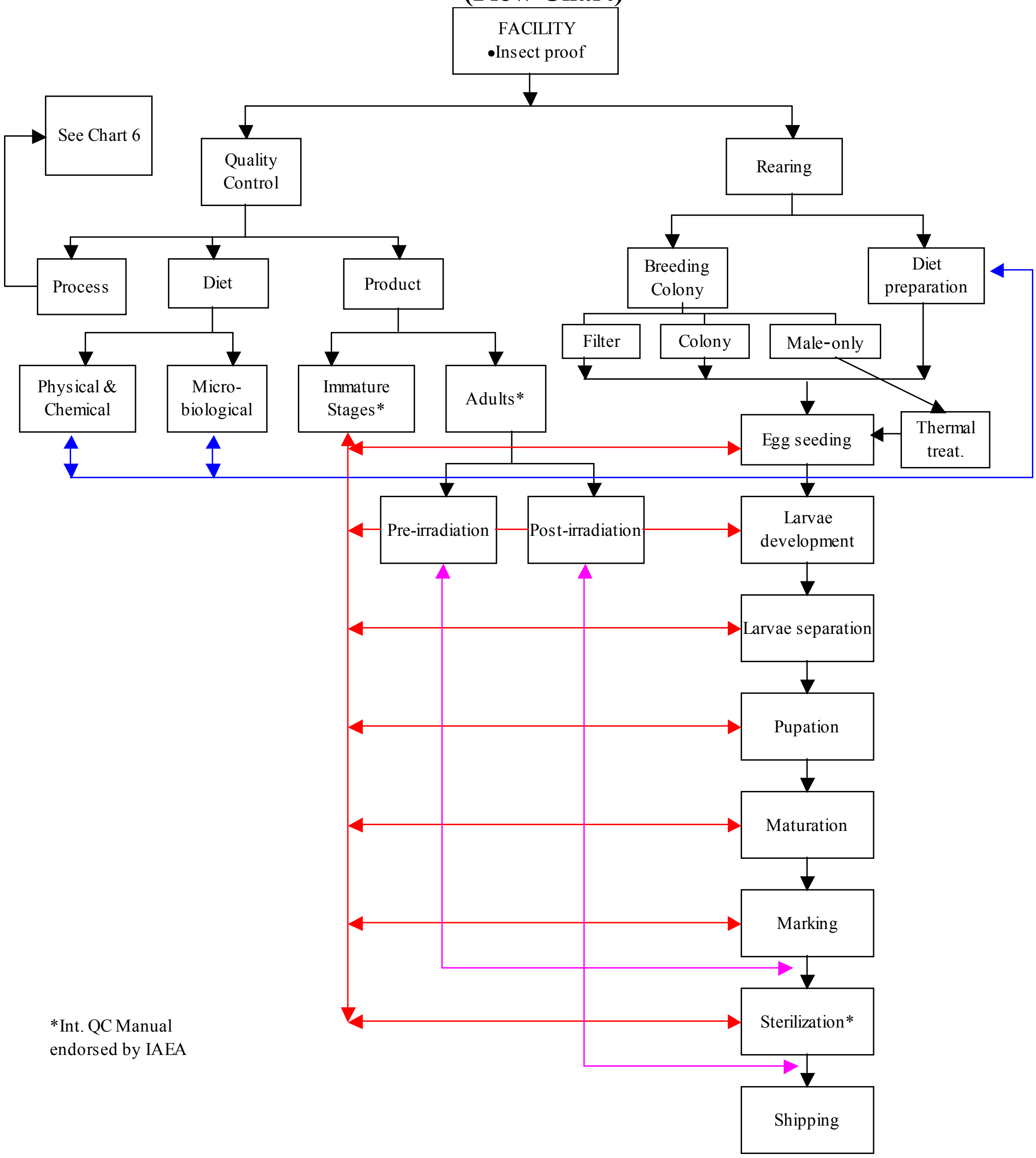


Floor plans for the *Bactrocera curcurbitae* production facility in Okinawa Prefecture, Japan, where melon fly was declared eradicated in 1993
(Source: Bakri, A. 2001, Slide show #16 on IDIDAS web site, http://www-infocris.iaea.org/ididas/.)

Flow charts[29] of each step of the production process

1. PRODUCTION

(Flow Chart)



The overall process (Flow Chart 1. Production) shows the flow of operations (black arrows). Blue arrows show quality control (QC) on diet ingredients, red arrows show QC on immature stages and purple arrows show QC on the adult stage (i.e. pre and post irradiation)

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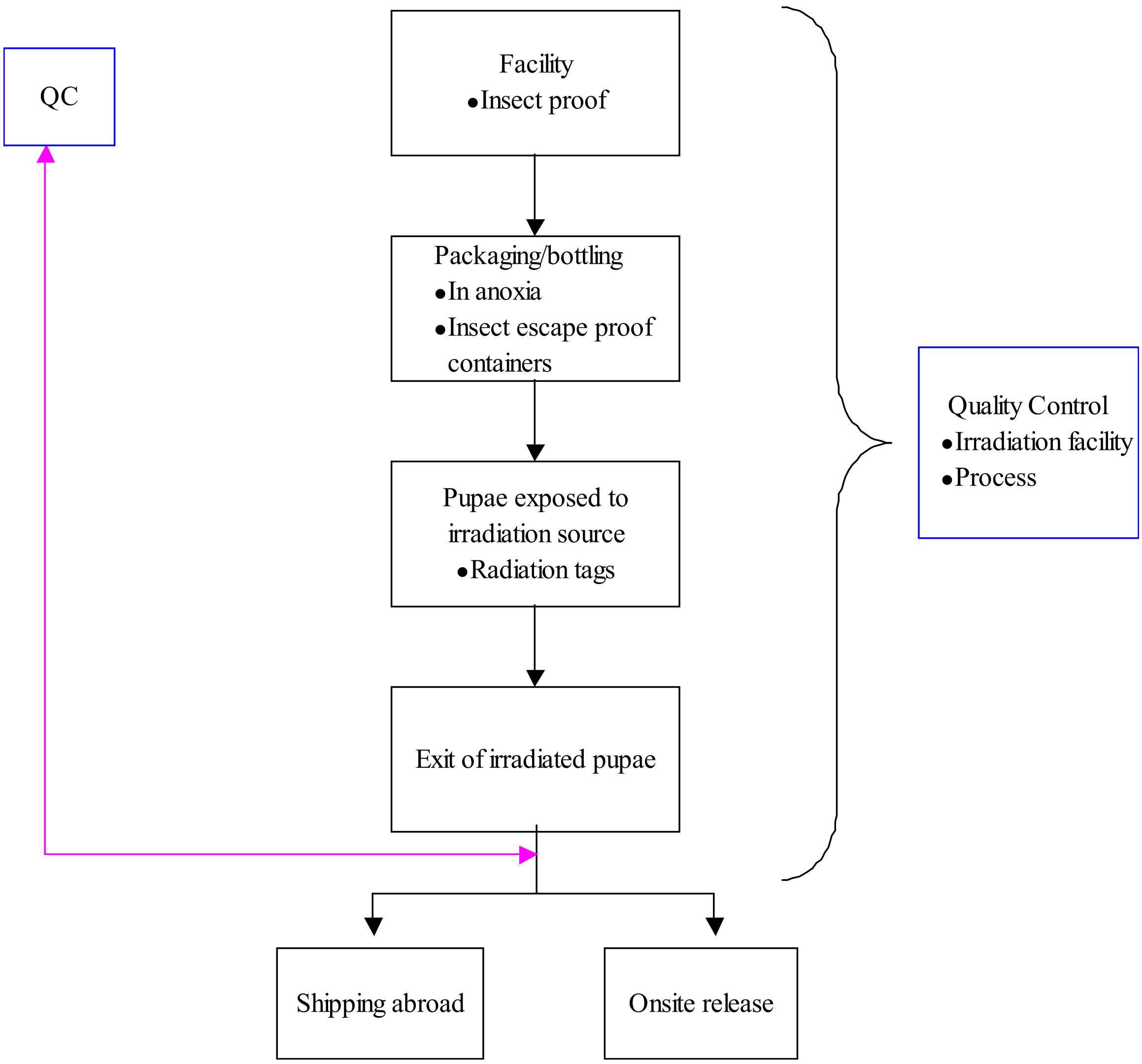
[29] Source of all flow charts is Enkerlin, 2001a, which is an unpublished presentation to the Consultants Group on Transboundary Shipment of Sterile Insects, 30 July to 3 August 2001, IAEA, Vienna, Austria (FAO/IAEA 2001a).

2. STERILIZATION

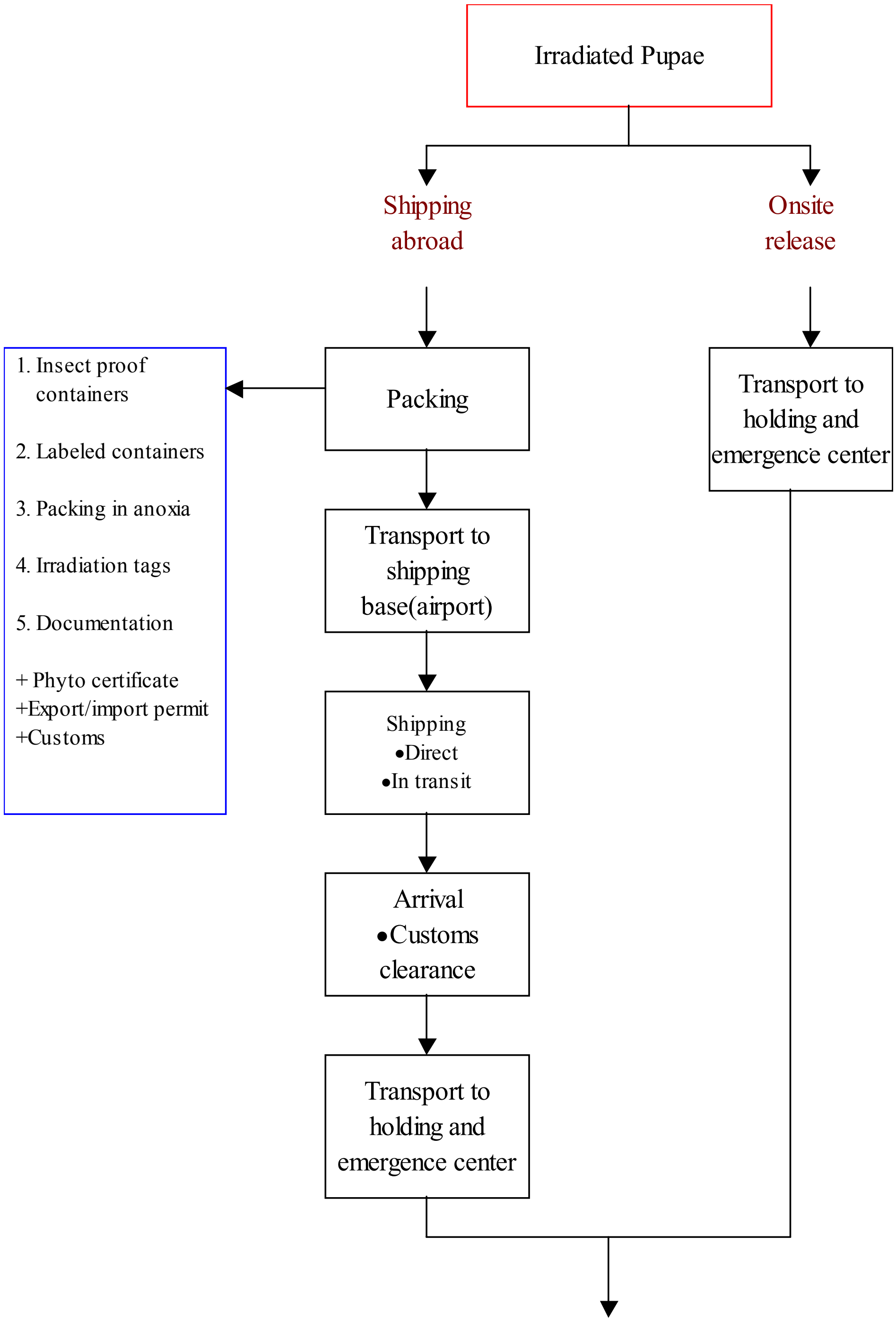
(Flow Chart)



This chart presents the flow of activities of the sterilization process. The blue box at the right hand of the chart indicates that QC is carried out for all the steps in the process. The purple arrows coming out from the blue box at the left hand indicate QC on the adult stage after irradiation.

3. SHIPPING

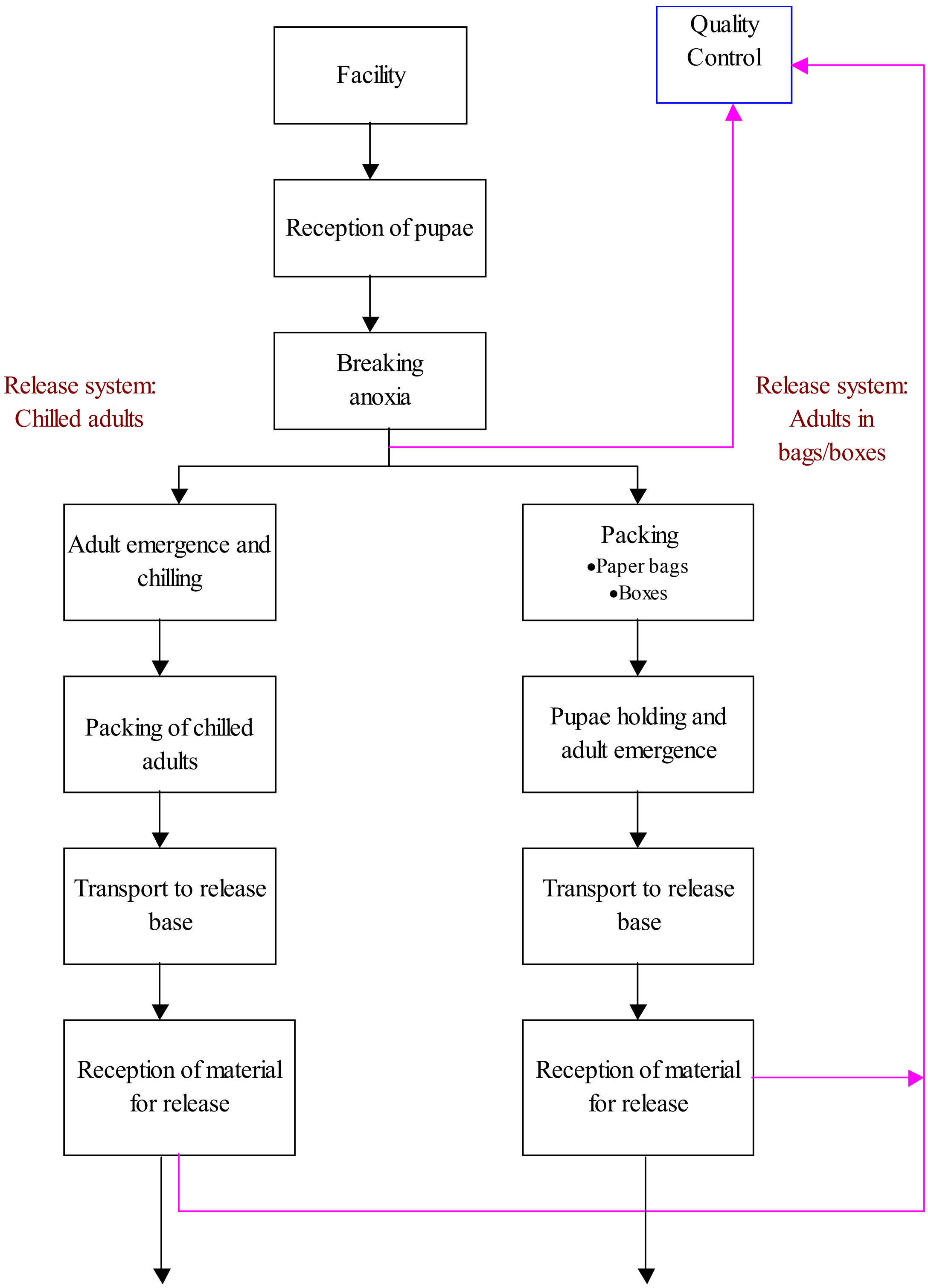
(Flow Chart)



Sterile insects are prepared for either local release or for shipping (Flow Chart 3) to a more distant location. This may be another country, or simply a different region. In these cases, the holding and emergence (Flow Chart 4) takes place near the location of the ultimate release of the sterile insects. The blue box lists the requirements to protect the integrity of the package content and assure safe delivery.

4. HOLDING & EMERGENCE

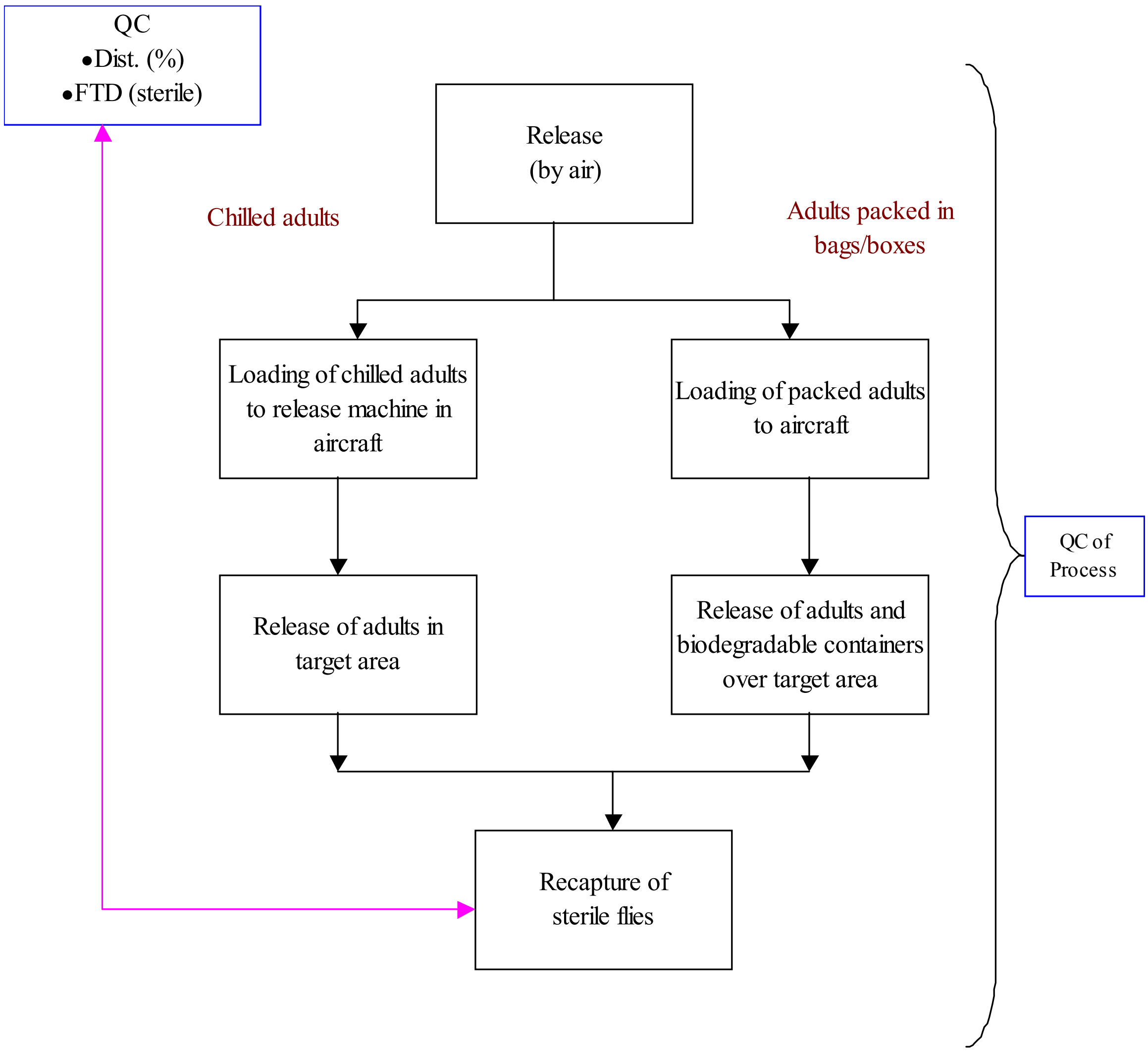
(Flow Chart)



Purple arrows indicate QC tests are carried out to irradiated adults from pupae collected after breaking anoxia and before shipment and to irradiated adults that have been transported to the release base before they are released.

5. RELEASE

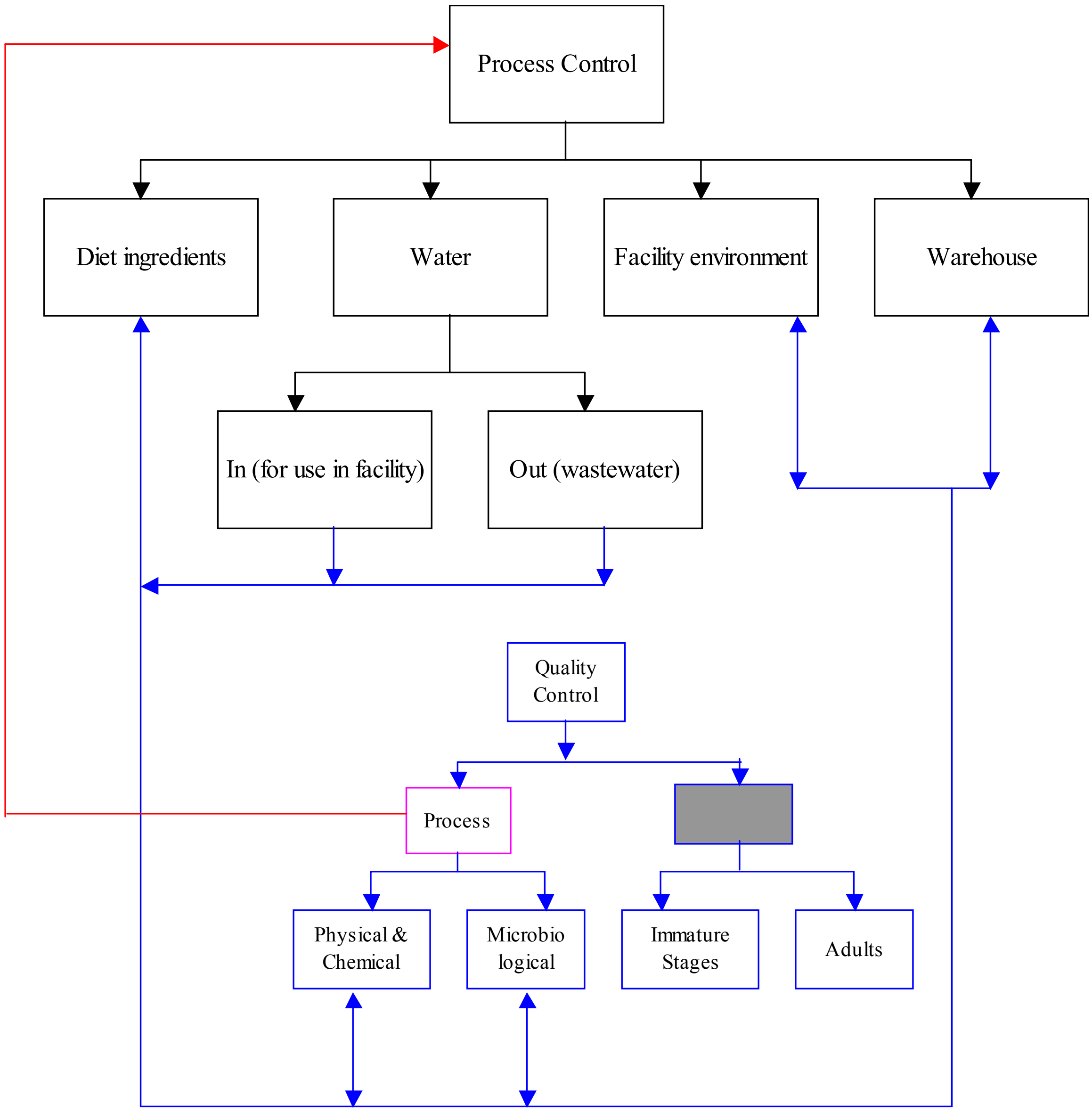
(Flow Chart)



The blue box at the right of the chart indicates QC is carried out for the full release process. This QC is only done if needed. The sterile insects may be released from aircraft (Flow Chart 5) designed for this purpose by free release (chilled adults) or in containers (e.g. paper bags) designed to allow escape of the insects. Purple arrows indicate QC on recaptured adults for feedback to field operations and the production facility managers regarding parameters such as: sterility, distribution and abundance of sterile flies and sterile:fertile (wild) ratios.

6. PROCESS CONTROL

(Flow Chart)



QC is in place for the product but also for the basic inputs of the production process as indicated by the purple box in this chart and the blue arrows. By maintaining this feedback from monitoring quality of the product, the environment, the effluent, etc, changes can be made to adjust and improve quality during the production process (red arrow).

Annex 8
Addressing hazards

A8.1 Example of Table of Contents for Standard Operating Procedures

- Colony maintenance
- Egg preparation
- Egg incubation
  - For colony production
  - For field release production
- Larval diet preparation
- Diet seeding
- Larval initiation (larvae room I)
- Larval maturation (larvae room II)
- Larval collection
- Pupation
- Pupa/vermiculite separation
- Pupal maturation
- Distribution of pupae
- Preparation of pupae for irradiation
- Irradiation
- Pupal dying, packaging and feeding

Source: L. Beans and B. Barnes. 2000.

A8.2 Emergency preparedness plans

In case of fire or other disaster such as flooding, earthquakes or hurricane, the following should be included in the emergency preparedness plan at a minimum:

- escape procedures and escape route assignments;
- plan for critical plant operations before evacuating;
- plan to account for all persons at the location;
- rescue and medical procedures (including basic first aid);
- preferred means of contacting the emergency services.

To design such an overall plan, an assessment of the vulnerability of the buildings and infrastructure to disasters must be undertaken. Needless to say, the resistance to damage by hazard events must be increased by taking preventative measures. Included in the assessment should be a study of the local region and what susceptibilities to disasters such as earthquakes, floods or landslides etc. exist. Most of the information required can be gathered from contacting local emergency services/government agencies.

A fire alarm system must be put in place that complies with local regulations. Lists must be posted of the major fire hazards at the location, including their proper handling and storage procedures, potential ignition sources (welding, smoking etc.). There must be also visible instructions as to the type of fire protection equipment that would be most appropriate, should a particular listed fire hazard ignite. Names and job-titles of those responsible for fuel source hazards, including those responsible for the maintenance of fire prevention equipment should be listed. The employer should control accumulations of hazardous waste materials and residues so that they do not contribute to a disaster. These “housekeeping” procedures should be written in the emergency preparedness plan.

Safety reference documents for the irradiation source[30]

Important publications for reference in planning the safety of the facility include:

- IAEA. 1997. Method for the development of emergency response preparedness for nuclear or radiological accidents. IAEA-TECDOC-953.

- IAEA. 2006. Development and Review of Plant Specific Emergency Operating Procedures. Safety Reports Series No. 48.

- IAEA. 1992. Radiation safety of gamma and electron irradiation facilities. Safety Series No. 107, International Atomic Energy Agency, Vienna.

- IAEA. 2003. CD Rom Version. International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources: A Safety Standard Safety Series No. 115 (Jointly sponsored by FAO, IAEA, ILO, OECD/NEA, PAHO and WHO).

- IAEA. 2006. Fundamental Safety Principles. *Safety Standards Series no. SF-1.* IAEA, Vienna. 21 pp.

Another publication also well-known in the field is: *"Safety considerations in the design of gamma irradiation facilities and the handling of cobalt-60 sources", by R.G. McKinnon, Radiation Physics and Chemistry, 31 (1988*).

IAEA provides guidance and establishes requirements on safety considerations and emergency preparedness related to the use of an irradiation source. The Fundamental Safety Principles specify the fundamental safety objective and a coherent set of ten safety principles established by international consensus. The ten safety principles constitute the basis on which to establish safety requirements for protection against exposure to ionizing radiation. They provide

[30] Information on these publications can be accessed at:
http://www-ns.iaea.org/standards/
http://www-ns.iaea.org/standards/documents/default.asp?sub=100
http://www-ns.iaea.org/standards/documents/default.asp?sub=250

the basis for the requirements in IAEA Safety Standards for the control of occupational, public and medical exposures and for the safety of sources. The Safety Fundamentals also provide an insight into the general system of protection and safety for those at senior levels in government and regulatory bodies and those responsible for making decisions relating to the uses of radiation in medicine, industry, agriculture, research and other areas.

A8.3 International conventions, agreements and protocols and regional bodies that may influence national regulation of sterile insects

Section 5.6 discusses some international conventions, agreements and protocols that may influence national regulation the production, shipment and release of sterile insects. On occasion, sterile insects have been accidentally covered by national regulations, rather than intentionally considered. The recent references to SIT in international standards should lessen this problem. The following table indicates current membership in the relevant organizations, or conventions. For more information on the ramifications of membership, see Section 5.6.

The table below also shows membership in the European Union (EU), since European Directives that may impact sterile insect trade and release apply to all of those countries. Many candidate countries will adopt similar legislation in anticipation of joining the EU. The Regional Plant Protection Organization covering that region is the European and Mediterranean Plant Protection Organization (EPPO), whose membership is also noted to show its range of influence even beyond the EU.

TABLE A8.1 COUNTRY MEMBERSHIP IN INTERNATIONAL AND EXAMPLE REGIONAL BODIES RELATED TO REGULATION OF PESTS AND RELEASE OF STERILE INSECTS FOR PEST CONTROL

(May 2006)

Country	CBD signatory **o** party **X**	CP signatory **o** party **X**	WTO	OIE	IPPC	EU pre-accession **o** member **X**	EPPO (example of an RPPO)
Afghanistan	X			X			
Albania	X	X	X	X	X		X
Algeria	X	X		X	X		X
Andorra				X			
Angola	X		X	X			
Antigua and Barbuda	X	X	X		X		
Argentina	X	X	X	X	X		
Armenia	X	X	X	X			
Australia	X		X	X	X		
Austria	X	X	X	X	X	X	X
Azerbaijan	X	X		X	X		
Bahamas	X	X			X		
Bahrain (Kingdom of Bahrain)	X		X	X	X		
Bangladesh	X	X	X	X	X		
Barbados	X	X	X	X	X		
Belarus	X	X		X	X		X
Belgium	X	X	X	X	X	X	X
Belize	X	X	X	X	X		
Benin	X	X	X	X			
Bhutan	X	X		X	X		
Bolivia	X	X	X	X	X		
Bosnia and Herzegovina	X			X	X		
Botswana	X	X	X	X			
Brazil	X	X	X	X	X		
Brunei Darussalam			X	X			
Bulgaria	X	X	X	X	X	o	X
Burkina Faso	X	X	X	X	X		
Burundi	X		X	X	X		

Country	**CBD** signatory **o** party **X**	**CP** signatory **o** party **X**	**WTO**	**OIE**	**IPPC**	**EU** pre-accession **o** member **X**	**EPPO (example of an RPPO)**
Cambodia	X	X	X	X	X		
Cameroon	X	X	X	X	X		
Canada	X	o	X	X	X		
Cape Verde	X	X			X		
Central African Republic	X	o	X	X	X		
Chad	X	o	X	X	X		
Chile	X	o	X	X	X		
China (People's Republic of China)	X	X	X	X	X		
Chinese Taipei (Taiwan or ROC)			X	X			
Colombia	X	X	X	X	X		
Comoros	X			X			
Congo, Democratic Republic of the	X	X	X	X			
Congo, Republic of	X	o	X	X	X		
Cook Islands	X	o			X		
Costa Rica	X	o	X	X	X		
Côte d'Ivoire	X		X	X	X		
Croatia	X	X	X	X	X	o	X
Cuba	X	X	X	X	X		
Cyprus	X	X	X	X	X	X	X
Czech Republic	X	X	X	X	X	X	X
Denmark	X	X	X	X	X	X	X
Djibouti	X	X	X	X			
Dominica	X	X	X		X		
Dominican Republic	X	X	X	X	X		
Ecuador	X	X	X	X	X		
Egypt	X	X	X	X	X		
El Salvador	X	X	X	X	X		
Equatorial Guinea	X			X	X		

Country	**CBD** signatory **o** party **X**	**CP** signatory **o** party **X**	**WTO**	**OIE**	**IPPC**	**EU** pre-accession **o** member **X**	**EPPO (example of an RPPO)**
Eritrea	X	X		X	X		
Estonia	X	X	X	X	X	X	X
Ethiopia	X	X		X	X		
European Communities	X	X	X		X		
Fiji	X	X	X		X		
Finland	X	X	X	X	X	X	X
France	X	X	X	X	X	X	X
Gabon	X		X	X			
Gambia	X	X	X	X			
Georgia	X		X	X			
Germany	X	X	X	X	X	X	X
Ghana	X	X	X	X	X		
Greece	X	X	X	X	X	X	X
Grenada	X	X	X		X		
Guatemala	X	X	X	X	X		
Guernsey*							X
Guinea, Republic of	X	O	X	X	X		
Guinea Bissau	X		X	X			
Guyana	X		X	X	X		
Haiti	X	O	X	X	X		
Honduras	X	O	X	X	X		
Hong Kong, China**			X				
Hungary	X	X	X	X	X	X	X
Iceland	X	O	X	X	X		
India	X	X	X	X	X		
Indonesia	X	X	X	X	X		
Iran (Islamic Republic of)	X	X		X	X		
Iraq				X	X		
Ireland	X	X	X	X	X	X	X
Israel	X		X	X	X		X
Italy	X	X	X	X	X	X	X

Country	**CBD** signatory **o** party **X**	**CP** signatory **o** party **X**	**WTO**	**OIE**	**IPPC**	**EU** pre-accession **o** member **X**	**EPPO (example of an RPPO)**
Jamaica	X	O	X	X	X		
Japan	X	X	X	X	X		
Jersey*							X
Jordan	X	X	X	X	X		X
Kazakhstan	X			X			X
Kenya	X	X	X	X	X		
Kiribati	X	X					
Korea, Democratic People's Republic of	X	X		X	X		
Korea, Republic of	X	O	X	X	X		
Kuwait	X		X	X			
Kyrgyzstan (Kyrgyz Republic)	X	X	X	X	X		X
Lao People's Democratic Republic	X	X		X	X		
Latvia	X	X	X	X	X	X	X
Lebanon	X			X	X		
Lesotho	X	X	X	X			
Liberia	X	X			X		
Libyan Arab Jamahiriya	X	X		X	X		
Liechtenstein	X		X				
Lithuania	X	X	X	X	X	X	X
Luxembourg	X	X	X	X	X	X	X
Macao, China**			X				
Macedonia, Former Yugoslav Republic of	X	X	X	X	X	o	X
Madagascar	X	X	X	X	X		
Malawi	X	O	X	X	X		
Malaysia	X	X	X	X	X		
Maldives	X	X	X				
Mali	X	X	X	X	X		

Country	**CBD** signatory **o** party **X**	**CP** signatory **o** party **X**	**WTO**	**OIE**	**IPPC**	**EU** pre-accession **o** member **X**	**EPPO (example of an RPPO)**
Malta	X		X	X	X	X	X
Marshall Islands	X	X					
Mauritania	X	X	X	X	X		
Mauritius	X	X	X	X	X		
Mexico	X	X	X	X	X		
Micronesia (Federal States of)	X						
Moldova	X	X	X	X	X		
Monaco	X	O					
Mongolia	X	X	X	X			
Morocco	X	O	X	X	X		X
Mozambique	X	X	X	X			
Myanmar	X	O	X	X	X		
Namibia	X	X	X	X			
Nauru	X	X					
Nepal	X	O	X	X	X		
Netherlands	X	X	X	X	X	X	X
New Caledonia				X			
New Zealand	X	X	X	X	X		
Nicaragua	X	X	X	X	X		
Niger	X	X	X	X	X		
Nigeria	X	X	X	X	X		
Niue	X	X			X		
Norway	X	X	X	X	X		X
Oman	X	X	X	X	X		
Pakistan	X	O	X	X	X		
Palau	X	X					
Panama	X	X	X	X	X		
Papua New Guinea	X	X	X		X		
Paraguay	X	X	X	X	X		
Peru	X	X	X	X	X		

Country	**CBD** signatory **o** party **X**	**CP** signatory **o** party **X**	**WTO**	**OIE**	**IPPC**	**EU** pre-accession **o** member **X**	**EPPO (example of an RPPO)**
Philippines	X	O	X	X	X		
Poland	X	X	X	X	X	X	X
Portugal	X	X	X	X	X	X	X
Qatar	X		X	X			
Romania	X	X	X	X	X	o	X
Russia (Russian Federation)	X			X	X		X
Rwanda	X	X	X	X			
Saint Kitts and Nevis	X	X	X		X		
Saint Lucia	X	X	X		X		
Saint Vincent and the Grenadines	X	X	X		X		
Samoa	X	X			X		
San Marino	X						
Sao Tome and Principe	X			X	X		
Saudi Arabia	X		X	X	X		
Senegal	X	X	X	X	X		
Serbia and Montenegro	X	X		X	X		X
Seychelles	X	X			X		
Sierra Leone	X		X	X	X		
Singapore	X		X	X			
Slovakia	X	X	X	X	X	X	X
Slovenia	X	X	X	X	X	X	X
Solomon Islands	X	X	X		X		
Somalia				X			
South Africa	X	X	X	X	X		
Spain	X	X	X	X	X	X	X
Sri Lanka	X	X	X	X	X		
Sudan	X	X		X	X		
Suriname	X		X	X	X		
Swaziland	X	X	X	X	X		
Sweden	X	X	X	X	X	X	X

Country	CBD signatory **o** party **X**	CP signatory **o** party **X**	WTO	OIE	IPPC	EU pre-accession **o** member **X**	EPPO (example of an RPPO)
Switzerland	X	X	X	X	X		X
Syria (Syrian Arab Republic)	X	X		X	X		
Tajikistan	X	X		X			
Tanzania, United Republic of	X	X	X	X	X		
Thailand	X	X	X	X	X		
Togo	X	X	X	X	X		
Tonga	X	X			X		
Trinidad and Tobago	X	X	X	X	X		
Tunisia	X	X	X	X	X		X
Turkey	X	X	X	X	X	o	X
Turkmenistan	X			X			
Tuvalu	X						
Uganda	X	X	X	X			
Ukraine	X	X		X	X		X
United Arab Emirates	X		X	X	X		
United Kingdom	X	X	X	X	X	X	X
United States of America	o		X	X	X		
Uruguay	X	O	X	X	X		
Uzbekistan	X			X			X
Vanuatu	X			X			
Venezuela (Bolivarian Republic of Venezuela)	X	X	X	X	X		
Viet Nam	X	X		X	X		
Yemen	X	X		X	X		
Zambia	X	X	X	X	X		
Zimbabwe	X	X	X	X			
Total Number of Contracting Parties	**188**	**133**	**149**	**167**	**153**	**25 members** **4 candidate states**	**47**

* Guernsey and Jersey – as with the rest of the Channel Islands – are British crown dependencies, and thus Britain is responsible for its external affairs. The EU considers the Channel Islands to be part of the UK in regard to trade (e.g., plant health), although these islands are outside the EU fiscal area.

** Hong Kong and Macao are now Special Administrative Regions of the People's Republic of China, but held these memberships independently prior to change.

However, in accordance with the Basic Law of the Hong Kong Special Administrative Region of the PRC, the Government of the PRC has indicated that the International Plant Protection Convention shall not apply to the Hong Kong Special Administrative Region.

For up to the date information on membership see the following web sites:

Convention on Biological Diversity and the Cartagena Protocol - www.biodiv.org

World Trade Organization - www.wto.org

World Organisation for Animal Health (formerly known as Office International des Epizooties) - www.oie.int

International Plant Protection Convention - www.ippc.int

European Union - www.europa.eu.int

European and Mediterranean Plant Protection Organization - www.eppo.org

Annex 9
SWOT Analysis

A strengths, weaknesses, opportunities and threats (SWOT) analysis of a business concept is frequently performed in business planning. This model business plan raises a number of issues related to the production phase of Sterile Insect Technique (SIT). Many of these issues can be seen as strengths or weaknesses, depending on the situation and the decisions made over the next months and years. Most tend to be positive or negative in terms of moving into privately owned/operated or joint venture facilities. This perspective is represented here.

Strengths	**Weaknesses**	**Opportunities**	**Threats**
Effective for eradication, exclusion and suppression Non-self replicating populations do not persist once releases are stopped Does not introduce an exotic spp (except in preventative release) Species specific, no non-target organism effects Sterile males seek out wild females, works at a low population level Benefits generally are distributed over a wider group of people Improving effectiveness as a pest management technology Environmentally acceptable, reduces insecticide use No problem with disposal of unused product Complementary to biocontrol Cost sharing of production possible Backup production available for some spp Some standard operating procedures (SOPs) in place Cooperative support for technology	For many pest spp SIT not developed or not appropriate Dispersed hosts or non-commercial hosts may be considered too costly Genetic variation within spp may affect performance Needs initial suppression/requires some pesticide Need for wide awareness and agreement in the release area Often cannot stand alone May require other steps to harness all benefits Challenges of working with living organisms Some SOPs, international regulations missing Initial capital cost of constructing facility, until sufficient supplies are available Lack of financial data for costing production of a new spp New type of technology for commercialization, or privatization – few case studies or models	Preventative releases Situations of pesticide resistance or host transfer Increasing costs associated with development of new pesticides Threat of further banning of major pesticides African commitment to tsetse control Rise of incidence of vector-borne human diseases and limitations of controls in place Interest of private investors Use of this model business plan Wide scale application encourages R&D Increasing need for eradication of exotic introductions Increased concern for food safety Alternative to control measures that negatively impact the environment	Pesticide industry is well entrenched Desire for own small production facility may lack the economy of scale If long-term political commitment falters, benefits of SIT (and facility construction) may be lost Reputation of SIT if the private sector does not maintain quality Private protection of new intellectual property (IP) Joint research requires IP protection Threat of over-regulation by individual countries Misunderstanding of biotechnology may attribute risks that are not valid

Strengths

- The long "track record" of safe and effective use of SIT for several key species of pests of plants and animals, for eradication, suppression and exclusion.
- The released organisms are not self-replicating so do not persist in the environment and their release can be stopped at any time.
- For control programmes SIT does not introduce exotic pest spp (although for preventative release the target spp may be classified as exotic)
- SIT is species specific and does not cause impacts on non-target organisms.
- SIT has an inverse density dependent relationship that makes it more effective as populations decline, therefore ideal for eradication and low level suppression.
- SIT agents actively search out wild female populations.
- SIT is normally applied on a large scale, thus benefits are likely to be both larger and more widely and equitably distributed than more localized (e.g. farm level) control methods.
- The quality improvements in SIT in terms of genetic strains, production technologies, survival rates in shipping, and tools for field programmes.
- The cost improvements in SIT from genetic sexing strains, production automation and field operations.
- Responds to the growing demand for reduced use of pesticides.
- No environmental issues for disposal of unused product (as with pesticides).
- SIT integrates well with other approaches, including release of biological control agents.
- Pre-SIT suppression may involve conventional pest control that has negative impacts, but it will be for a much shorter period compared to continued conventional control.
- Production may be shipped to supply suppression/eradication programmes without the total cost falling to one country or region.
- In some cases, multiple production sites allow for some insurance against a total loss of supply in case of a catastrophic drop in output.
- Harmonized standard operating procedures exist for some species and a mechanism exists to support development for other species.
- Management/owners of production facilities have a culture of cooperation and mutual support.
- Top experts in research, production and field operations are employed by governments or international bodies that are open to sharing improvements and innovations.

Weaknesses

- The lack of a "track record" for a number of important pest species that may lend themselves to SIT, or are close to field success for SIT.
- Not all important pest species lend themselves to SIT for biological reasons (for example, due to the damage caused by the adult stage; several key pests present multiple mating; species complexes could require a range of sterile strains, etc.).
- Some important pests are uneconomic for SIT (for example, due to very high mobility to reinvade, in which case SIT could be a preventive approach before insects disperse, etc.).
- Dispersed or intercropped hosts generally make SIT more costly per unit area, although it can still be effective. Large areas of non-commercial hosts which dilute benefits.
- Differences in genetic strains or populations that may reduce success rate, or lack of sufficient difference to prevent cross-species breeding, requires expensive field work and research.

- Needs initial suppression, which generally involves pesticide. SIT does not work as well in high density populations, because the sterile:wild ratio on release would be prohibitive.
- The need for community agreement and involvement to coordinate with SIT rather than taking individual actions such as spraying. The perception (versus actual level) of effectiveness that will lead to individual producers being willing to finance a product that is very different from agrochemicals.
- SIT is often part of an integrated control programme and cannot stand alone.
- Because SIT normally operates on an area-wide scale the impacts are likely to be large and may require parallel commitment to other aspects of management to harness the benefits appropriately (for example, successful vector control may have important land-use implications that would need careful management).
- SIT is management intensive, requiring high quality control and low mortality throughout the chain (establishing a colony, production, sterilization, shipping, release and surveillance). Working with living organisms is challenging.
- The need for an initial, relatively large investment for a production facility before achieving any benefits from SIT (unless imports are used).
- The lack of financial data from government-owned facilities makes it difficult to be sure about the true costs of long-term production; private facilities will be less forthcoming. Production of a new species is not yet costed.
- General lack of case studies or models for commercialization or privatization.

Opportunities

- The demonstrated success (and cost reductions) of using preventative releases rather than waiting for outbreaks of the targeted invasive species to occur.
- Because SIT is species-specific, it is an effective option in situations of pesticide resistance or host transfer in response to rotation of crops, or other failures of control methods.
- The increased costs of development of new pesticides and pressure to ban many major pesticides require alternative approaches.
- The wide-spread commitment by African nations to management of tsetse as a serious source of disease that can be controlled.
- The global rise of human disease from insect vectors and failure of existing technologies (including vaccination, treatment or prophylactics) to protect populations at risk.
- Countries and private investors may use the information now available in this model business plan to support wise decisions about production facility capacity and location.
- Long-term suppression programmes and more widespread implementation of an area-wide approach create opportunities for private investment and a stimulus to research and development.
- The increase in world trade and opening of new trade routes has allowed more introductions of exotic pests, which require control or eradication.
- Increased concern over food safety and pesticide residues supports reduced uses of chemicals.
- Concerns over environmental impact from the pests themselves and the control measures encourage integrated programmes that use less of pesticides.

Threats

- Pesticide industry is well entrenched globally and will begin to see SIT as more of a competitor.
- Each project or country may want their own production facility, thereby leading to uneconomic oversupply, lack of economies of scale or poor quality production that leads to failure, which gives a bad reputation to SIT.
- Time is required to maximize the benefits of SIT, and of construction of production facilities. Continuation of the political commitment is crucial to realize the full benefits.
- There will be less control over private facilities selling to private release programmes, so that the overall reputation of SIT could suffer if mistakes are made.
- New improvements or innovations developed by the private sector may be less available to public programmes if proper contractual or intellectual property protection is not in place.
- Joint research may be restricted by the lack of intellectual property protection for the privately funded portion of the work.
- Over-regulation, poorly designed regulation, or uncertainty caused by lack of regulation could stifle investment, application and innovation in SIT.
- There is a lot of misunderstanding of biotechnology (versus genetic modification). Public opinion may attribute risks that are not valid to genetically linked sexing or use of marker genes in non-replicating populations.

Annex 10
Contents of specific business plans

This report discusses business planning for sterile insect production facilities. A business plan will be needed for each individual business. This annex provides the outline for a business plan for any type of business. While sterile insect production has some unique features, a standard business plan can be prepared to cover these common factors of interest to private investors. If the production facility is owned by the government or by a growers' association, for example, aspects of the business plan may change. The exit strategy may be replaced by a plan for scheduled renovation or a mechanism for retiring growers to be bought out by new ones, similar to a cooperative.

The points may be covered in a different sequence but there should be a reason for not covering any points listed in this outline for a specific business plan.

Selection criteria for a site for a sterile insect production facility (as in Section 3.3) appear following the business plan contents.

Executive summary
Encompassing the main elements of the venture to be undertaken.

Company description
- History, including how any specific problems have been overcome.
- Figures, sales, profits, annual turnover.
- Present status and plans for the future.

Product/service
- A simple description of the product, what it does, and what makes it unique. One should describe here who the customers will be and what the market is for the product.
- Cost effectiveness.
- Patent situation or other plans for protection of intellectual property and use of others' patents.
- Revenue model: a model describing revenue sources for different aspects of the venture such as advertising/transactions/subscriptions and whether they will be flat fees or percentage based fees.
- Development status.
- Have there been similar ventures that have been successful in the past? Include examples if possible.
- Sustainability and the long-term effects of use of the product.

Management team
- Details of the founders and their qualifications/experience. One should describe how critical the founders are to the success of the project, and how responsibilities will be shared among the team (this could be done in table format).
- Plans to hire future managers (including skills required).

Market analysis and competition

- Potential market size as shown by an in-depth analysis.
- Industry characteristics including expected growth and what major factors will affect future growth, government regulations, technological opportunities, research developments (present and future).
- Competition: what strategies are used at present? What do they offer (advantages and disadvantages)? What is this business's competitive positioning?

Marketing and sales

- Promotional possibilities and marketing plans. Detail the cheapest to the most expensive marketing strategies and their respective advantages/disadvantages.
- Distribution plan. If this cannot be done in-house, details should be given of partners who would aid distribution (include costs).
- Pricing strategy. Detailing how much will be charged to the client per unit of product/service and discussing what is the basis of this pricing.

Operations plan

- Location. Building designs, infrastructure, access and local area maps.
- Structure of the company and how it will be run.
- Labour requirements (including skills required) and equipment needs.
- What can be performed in-house and what will need to be outsourced. Detail strategic partners for outsourcing and if there are none at present, include plans to get partners (e.g. key vendors).

Implementation schedule

- Detailed short-term plan on an estimated time scale. Include major milestones and where responsibilities lie regarding the management team. Are there interdependencies?
- 5-year implementation plan showing projected activities on a quarterly scale.
- Long-term options.

Opportunities and risk

- Examples of best and worst case scenarios for the short-term and in a 5- to 10-year plan.
- Identify the key assumptions in the business plan.
- Sensitivity analysis. What would be the outcome if key assumptions were varied in isolation?

Financial plan

- 5-years or ideally at least one year beyond break even point. Including cash flow statement, valuation (utilizing discounted cash flow analysis and revenue multiples) and a balance sheet.
- What are the key assumptions underlying the financial plans?
- What are the financial requirements for the venture? And what sources of financing have been identified?

Exit strategy

- Plan for the investor to get out of the investment (usually within three to seven years). This is usually in the form of a merger, acquisition or an initial purchase offering (going public). Or,
- A plan for the investor to receive dividends or repayment with interest in lieu of ultimate buy out.

Appendices

For attachments such as managers' résumés, product photos, building designs etc.

References for this annex

http://www.soyouwanna.com/site/syws/bizplan/bizplan3.html

Mckinsey and Company at a seminar for the Entrepreneurship Challenge, Imperial College, 6 March 2001.

SITE SELECTION FOR AN STERILE INSECT PRODUCTION FACILITY

Country selection for production facilities

Points to consider include:

- Costs of land acquisition, construction and operation of a production facility
- Proximity to markets
- Availability of appropriate sites (necessary attributes discussed in the next section)
- Transport system for land or air cargo
- Availability of a work force that can be trained in the necessary skills
- Political stability of the country
- Levels/types of crime
- Risk of natural disasters
- Vulnerability of the location to the escape of the species produced (in balance with the proximity of market issue)
- Approval or even support from the country government for this activity

Specific site selection

Only sites of adequate size for all future expansion plans and of an affordable cost should be subjected to additional criteria. Any site for a production facility will need a minimum level of infrastructure in order for someone to successfully do business. These minimum requirements include:

Physical infrastructure

- Access to affordable and steady supply electricity
- Good quality water supply
- Water treatment options
- Road systems
- Access to airport (if air shipment will be used)
- Reliable telecommunications services, including internet access
- Availability of inputs (original construction and on-going inputs such as diets for production)

Social attributes

- Proximity of an appropriate work force
- Absence of labour disputes in similar sectors
- Near a university for access to student labour
- Near research facilities if possible
- Overall safety of the area in regard to crime
- Absence of political unrest

Legislative attributes

- Clear land ownership system
- Favourable tax structures and clear investment laws
- Transparent regulation of intellectual property rights
- Incentives for investment
- Uncomplicated system for permits on buildings, zoning issues, or licenses

Bioecological attributes

- Ability of the species under production to live in the environment in the case of an escape (seasonal limitations on survival, host limitations)
- Effectiveness of monitoring tools that can establish if any escapes occur
- Availability of tools for control of an escape leading to an outbreak

Possible additional criteria for government-sponsored projects

- Employment opportunities for a targeted area
- Complementary to national plans for land use and environmentally appropriate industry
- Integration into scientific/technological parks
- Security and accessibility to irradiation source

Annex 11
Terms of Reference

Model Business Plan for a Sterile Insect Production Facility

In 2005 an update of this 2002 study was commissioned by the FAO/IAEA Joint Programme on Nuclear Techniques in Food and Agriculture, Insect Pest Control Sub-Programme. Revisions were to be based primarily on information appearing in the Subprogrammes biannual Insect Pest Control Newsletter and web site (found at http://www-naweb.iaea.org/nafa/index.html) and consultation with the Subprogrammes staff, rather than by conducting new studies or literature reviews. Most changes are incorporated into the text, although text boxes will be used to update annexes, in particular.

General business issues

The proposed project will identify and discuss the issues to be included in a model business plan for a sterile insect production facility. Issues common to all species of insects and locations, such as key competencies of staff and sales strategies, will be defined and addressed. The report is to be used as a critical assessment tool for any country or group of investors to apply when considering development of a sterile insect production facility.

This model plan will include an initial feasibility check list to be applied to new proposed locations before investing in more detailed analysis of the likelihood of commercial success. The likelihood of commercial success will be predicted using spread sheets which ultimately can be used by facility managers for regular monitoring after production has begun, as they will show the robustness of the operation by entering various indicators (e.g. variable costs of diet, changes in utility rates, biological variables such as an increase in mortality in transit, and so forth) that impact profit.

Markets

Commercial competitiveness issues will be addressed in this section and will come through to a large degree in the application of the model business plan's feasibility phase.

Current state of the art technology will encourage investment in species already shown to survive well in the laboratory environment and in field trials. Therefore global market analysis will begin with an overview of potential demand for sterile Mediterranean fruit fly (Medfly), *Ceratitis capitata*, and other economically significant fruit fly species that have a "track record" in mass rearing. More in-depth research on example Medfly markets of particular interest to the proposed Slovakian supplier (Portugal, Morocco and Tunisia) will be developed from on-site interviews. On-site interviews can pick up on issues, such as the motivation of the buyer and political will, which generally are not recorded in existing studies nor self reported through surveys.

The status of the tsetse fly (*Glossina* spp.) eradication campaign will be discussed because of its important role in creating a market for these species. Advantages and disadvantages related to the location of supplies will be noted. Other possible animal and public health initiatives that could benefit from the work done on this publicly funded example will be listed.

Regulations and logistics

Regulatory issues that may impact the proposed transport of sterile Medfly and tsetse fly from Slovakia will be included. Global regulatory issues that may impact transport of any sterile insect will be discussed for purposes of the generic business plan. Intellectual property concerns will be covered under this section.

Manufacturing and product description

Production technologies and operational issues will vary according to the species produced. Costs will vary by species as well as location of the facility. Generic aspects of issues such as quality control will be illustrated with the Slovakian example.

Financial information

Detailed financial information will be sought from existing sterile insect production facilities, both large and small scale, and both operational and research oriented. Spreadsheets noting the factors to be taken into account will be presented for the model business plan. Examples from other studies will best illustrate the use of these tools.

Synthesis of business plan

A synthesis of these independent parts of the business plan will be presented in an analysis of the strengths, weaknesses, opportunities and threats (SWOT) related to the generic sterile insect production facility and the conclusions of the report. Sensitivity analysis will allow future readers to adjust spreadsheets with any new information from research or more data from operating commercial facilities. Key risks for the model concept as well as the Slovakian example will complete the report.

Methodology

In order to complete the model business plan and the Slovakian example with the best information available today, consultations will take place with:

- IAEA Vienna;
- FAO Rome counterparts on tsetse;
- the Organisation of African Unity (OAU);
- managers of existing sterile insect production facilities;
- example governments already buying sterile insects;
- others that are expected to be future buyers;
- some potential investors;
- Slovakian authorities.

For logistics, regulatory and intellectual property issues consultations will include:

- example national governments (including Austria);
- the Secretariats of the International Plant Protection Convention, the Office of International Epizootics, and the World Health Organization;
- legal counsel;
- potential shipping agents.

A logical framework developed at the initiation of the project appears below.

Design elements	Verifiable indicators	Means of verification	Important assumptions
OVERALL OBJECTIVE Well-planned sterile insect production facilities are commercially successful and/or providing product for public good program within budget.	Sterile insects used in appropriate insect control programs.	Production facilities will be producing insects used in sterile release programs.	The generic business plan will be applied at the appropriate stage in project design and followed over time.
SPECIFIC OBJECTIVES Generic business plan for sterile insect production facilities is completed and applied to example case (Slovakian proposal).	Project report is accepted by IAEA.	Final report incorporates any comments.	Both quantitative data and non-quantifiable issues (e.g. possibility of civil unrest) are reflected in the model.
PROJECT OUTPUTS 1) Financial and business factors of sterile insect production facilities are reflected in model business plan and applied to Slovakian case. 2) Manufacturing techniques and product are illustrated, gaps needing research are identified. 3) Potential logistics and regulatory barriers or bottlenecks are noted. 4) Market for sterile insects is analysed and this is related to Slovakian case. 5) General business principles involved in the construction and operation of sterile insect production facilities are discussed for both profit ventures and public good programs.	1) Case study presents results with real data. 2) Critical R&D for improved manufacturing and handling is identified. 3) International guidance developed for regulating perceived risk from production and transport of sterile insects. 4) Markets for species covered are presented with assumptions for future changes. 5) Information presented appropriate to business plan and potential investors.	Draft report submitted for review.	Accurate data is coupled with quality analysis.
ACTIVITIES • Existing studies on technology and manufacturing reviewed. • Financial models developed. • Data collected from existing facilities. • Slovakian information obtained. • Market analysis from existing studies. • On-site market studies. (Portugal, Tunisia, Morocco) • Logistics and regulatory review. • Generic issues identified for this type of business.	Each component of report is covered.	Note to contracting officer on where response to each part of terms of reference can be found in draft report.	Collaborators willing to meet. Existing facilities have data in form usable for this project. Data needed for market analysis is accurate and available.
PROVIDED IAEA, Government of Slovakia and existing sterile insect production projects inputs: internal expertise and existing studies • information from IAEA collaborators (e.g. May 2001 tsetse fly meeting) • information from Slovakia • data from existing facilities	Appointments with IAEA experts, overview of resource material to be consulted, information needs from Slovakian government and IAEA collaborators communicated, and team formed upon contracting.	Schedule of appointments to be kept. List of contacts from throughout project. Bibliography of materials consulted. Requests for information recorded with date of requests and replies.	***PRECONDITIONS*** Inputs are provided.

Annex 12
Acronyms, Abbreviations and Units

ACIAR	Australian Centre for International Agricultural Research
ADAM	Association de Developpement de l'Arboriculture au Maroc (Morocco)
AFFA	Department of Agriculture, Fisheries and Forestry – Australia
AIDS	autoimmune disease syndrome
AOAD	Arab Organization for Agricultural Development
APHIS	Animal and Plant Health Inspection Service (USDA)
APR	annual percentage rate
ARS	Agricultural Research Service (USDA)
ARASIA	Arab States in Asia
ATA	a unified customs document Admission Temporaire
BAT	bait annihilation treatment
BCA	biological control agent
BSE	bovine spongiform encephalopathy
Bt	*Bacillus thuringiensis*
ºC	degrees centigrade
CABI	CAB International (UK headquarters unless otherwise noted)
CACIAL	Cooperativa Agricola de Citricultores Do Algarve (Portugal)
CAPS	Cooperative Agriculture Pest Survey Program (USDA/APHIS)
CBD	Convention on Biological Diversity
CDC	Commonwealth Development Corporation (UK)
CDFA	California Department of Food and Agriculture
CEO	Chief Executive Officer
CGIAR	Consultative Group on International Agricultural Research
CIF	cost, insurance and freight
CI	cytoplasmic incompatibility
CIRDES	Centre International de Recherche et Development sur l'Elevage en Zone Subhumide (Burkina Faso)
CIS	Commonwealth of Independent States
CLAM	Comité de Liaison de l'Agrumiculture Méditerranéenne (Mediterranean Citrus Liaison)
CNCMF	Campaña Nacional Contra Moscas de la Fruta (Mexico)
CNMI	Commonwealth of the Northern Mariana Islands
CNSTN	Centre National des Sciences et Technologies Nucléaires (Tunisia)
^{60}Co	Cobalt-60
COCOM	Coordinating Committee for Multilateral Export Controls
COOC	California Olive Oil Council
COSAVE	Comite de Sanidad Vegetal del Cono Sur (RPPO)
CRDA	Commissariat Régional de Développement Agricole (Tunisia)
CREC	Citrus Research & Education Center (Florida)
CRP	Coordinated Research Project
^{137}Cs	caesium-137

DALYs	Disability-Adjusted Loss Years
DBCP	Dibromochloropropane
DDT	dichloro diphenyl trichloroethane
DGPV	Directeur Général de la Protection des Végétaux (Tunisia)
DGSV	Dirección General de Sanidad Vegetal (SAGARPA, Mexico)
DfID	Department for International Development (UK)
DFPT	Deciduous Fruit Producers' Trust
DOAE	Department of Agricultural Extension (Thailand)
DPVCTRF	Plant Protection Department (Morocco) *Direction de la protection des végétaux, des controles techniques et de la repression des fraudes*
DRC	Democratic Republic of Congo
DSBB	International Monetary Fund's Dissemination Standards Bulletin Board
EACCE	Etablissement autonome de contrôle et de coordination des exportations (Morocco)
EC	European Commission
ECIP	European Community Investment Partners
ECU	European Currency Unit (predating the Euro)
EDB	ethylene di-bromide
EDF	European Development Fund
EIA	Environmental Impact Assessment
EIB	European Investment Bank
ENA	Ecole Nationale d'Agriculture (Meknes, Morocco)
EPA	Environmental Protection Agency (USA)
EPPO	European and Mediterranean Plant Protection Organization
ERDF	European Regional Development Fund
ERGO	Environmental Research Group, Oxford University
EU	European Union, presently consisting of 27 Member States (sometimes referred to as EU-15 to distinguish the EU from other periods of time)
EWG	Environmental Working Group
EXIMBANK	Export-Import Bank of the United States
FAO	Food and Agriculture Organization
FDACS	Florida Department of Agriculture and Consumer Services
FDI	foreign direct investment
FITCA	Farming in Tsetse Controlled Areas
FV	future value
GDP	Gross Domestic Product
GIAF	Groupement Interprofessionel des Agrûmes et Fruits (Tunisia), now know as GIF
GIF	Groupement Interprofessionnel des Fruits
GM	genetically modified
GPPIS	Global Plant and Pest Information System
GSS	genetic sexing strains
Gy	Gray (equivalent to 100 rads) – see units used in this report

Ha	Hectare
HEPA	High efficiency particulate arrested
HIV	Human immuno-deficiency virus
HVAC	Heating, ventilation and air conditioning
IAEA	International Atomic Energy Agency
IBAR	International Bureau for Animal Resources (OAU)
IBRD	International Bank of Reconstruction and Development, often called the World Bank
ICCT	Institute for Combat and Control of Trypanosomiasis (Angola)
ICSID	International Centre for Settlement of International Disputes
IDA	International Development Association (World Bank)
IDB	Islamic Development Bank
IDIDAS	International Database on Insect Disinfestation and Sterilization (IAEA)
IDM	integrated disease management
IFAD	International Fund for Agricultural Development
IFC	International Finance Corporation (World Bank)
IICA	Instituto Interamericano de Cooperación para la Agricultura
ILO	International Labour Organization
INAT	Institut National Agronomique de Tunisie (Tunisia)
INE	Instituto Nacional de Estatística (Portugal)
INRA	Institut National de la Recherche Agronomique (Morocco)
INT	Interregional project of IAEA
IP	Intellectual Property
IPANET	Investment Promotion Network (World Bank)
IPM	Integrated Pest Management
IPPC	International Plant Protection Convention (deposited in FAO, Rome)
IPR	intellectual property rights
IRR	internal rate of return
ISAAA	International Service for the Application of Agri-biotech Applications
ISO	International Standards Organization
ISPM	International Standard for Phytosanitary Measures
IUCN	International Union for the Conservation of Nature and Natural Resources
JMOA	Jamaican Ministry of Agriculture
KETRI	Kenya Trypanosomosis Research Institute
Kg	Kilogram
Km	Kilometre
MAT	male annihilation techniques
MB	methyl bromide
MIGA	Multilateral Investment Guarantee Agency of the World Bank Group
MRL	maximum residue limit (generally related to pesticide residues)
Mt	metric tonne

NAPPO	North American Plant Protection Organisation
NCBA	National Cattlemen and Beef Association (USA)
NEA	Nuclear Energy Agency (OECD)
NGO	non-governmental organization
NPV	Net present value
NSEP	National Screwworm Eradication Project (Jamaica)
nvCJD	New variant Creutzfeldt-Jakob Disease
NWS	New World screwworm
NY convention	UN convention on the recognition and enforcement of arbitral awards
NZIER	New Zealand Institute of Economic Research
OAU	Organisation of African Unity
ODA	overseas development assistance
OECD	Organisation for Economic Cooperation and Development
OIE	World Organisation for Animal Health (formerly Office International des Epizooties) (Paris)
OIRSA	Organismo Internacional Regional de Sanidad Agropecuaria
OPEC	Organization of Petroleum Exporting Countries
OPIC	Overseas Private Investment Corporation (USA)
OSMT	Office of Standards, Metrology and Testing (Slovakia)
OWS	Old World s`crewworm
PAAT	Programme Against African Trypanosomiasis
PAHO	Pan American Health Organization
PANNA	Pesticide Action Network, North America division
PATTEC	Pan-African Tsetse and Trypanosome Expert Committee
PBW	pink bollworm
PIC	Prior Informed Consent
POP	persistent organic pollutant
PV	present value
QA	quality assurance
QC	quality control
Qfly	Queensland fruit fly
RADA	Rural Agricultural Development Authority (Jamaica)
R&D	research and development
RPPO	Regional Plant Protection Organization
R/PRA	rapid and participatory rural appraisal
RTTCP	Regional Tsetse and Trypanosomiasis Control Programme
SAG	Servicio Agricola y Ganadero (Chile)
SAGARPA	Secretaría de Agricultura, Ganadería, Desarollo Rural, Pesca y Alimentación (Mexico)
SARIO	Slovak Investment and Trade Development Agency
SASMA	Société Agricole de Services au Maroc (Morocco)
SCCI	Slovak Chamber of Commerce and Industry

SENASA	Servicio National de Sanidad y Calidad Agroalimentaria (Argentina)
SERST	Secrétariat d'Etat à la Recherche Scientifique et à la Technologie (Tunisia)
SI	standard international (units)
SIMEST	Italian development finance agency
SIR	sterile insect release
SIT	sterile insect technique
SME	small and medium sized enterprises
SONOPROV	Société Nationale de la Protection des Vegétaux (Tunisia)
SOP	standard operating procedure
SPS	Sanitary and Phytosanitary Measures (generally refers to the WTO Agreement on the application of sanitary and phytosanitary measures)
SWOT	an analysis of Strengths-Weaknesses-Opportunities-Threats
TBT	Technical Barriers to Trade (WTO Agreement)
TCPCS	Technical Co-operation Programmes Coordination Section, IAEA
TMRI	Tropical Medicine Research Centre (Sudan)
TRIPS	Trade-related Aspects of Intellectual Property Rights (WTO Agreement)
TTRI	Tsetse and Trypanosomiasis Research Institute (Tanzania)
UAE	United Arab Emirates
UK	United Kingdom
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNCITL	United Nations Commission on International Trade Law
URL	Uniform Resource Locator (Web site address)
US	Pertaining to the USA (e.g. US$)
USA	United States of America
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
VAT	Value Added Tax
WFS	World Food Summit
WHO	World Health Organization
WIPO	World Intellectual Property Organization
WTO	World Trade Organization
WWW	World Wide Web, also referred to as the Web

Units used in this report

The metric system (kilometres, metric tonnes, hectares, etc.) is employed, with equivalents in parentheses if required. Below are definitions for a number of units that are used in this report, for clarification purposes.

- kilogram (kg): a unit of mass, e.g. 1 kg, originally defined as the mass of one litre (10^{-3} cubic metres) of pure water;
- metric tonne (mt): a unit of mass, 1 mt = 1000 kilograms;
- metre (m) and kilometre (km): a metre is a unit of length;
- kilometres squared (km^2): the area of a square measuring 1 km on each side;
- hectare (ha): the area of a square measuring 100 metres on each side;
- litre (l): a measure of capacity in the metric system equal to a cubic decimetre;
- degree centigrade (ºC): a measure of temperature in the metric system equal to 273 Kelvin (K). To convert from centigrade to Fahrenheit one has to multiply by 1.8 and then add 32, e.g. 1ºC = 33.8ºF.
- Gray (Gy): a quantified measure (dose) of ionizing radiation absorbed; the absorption of one joule of radiation energy by one kilogram of matter.
- mn: million. In some countries 1 000 000 is referred to as 1000 thousands.

Conversion table of units used in this report

Metric unit	Other common equivalents
1 kilogram (kg)	2.205 pounds (lbs) = 35.27 ounces
1 metric tonne (mt)	1000 kg, approx. 2205 lbs, also known as a tonne
1 metre (m)	3.28 feet = 39.37 inches = 1.094 yards
1 kilometre (km)	0.62 miles (approx)
1 hectare (ha)	0.01 km^2 = 2.47 acres
1 litre (l)	0.22 gallons (UK) = 61.02 cubic inches
1 degree centigrade (ºC)	1.8 degrees Fahrenheit (ºF)

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