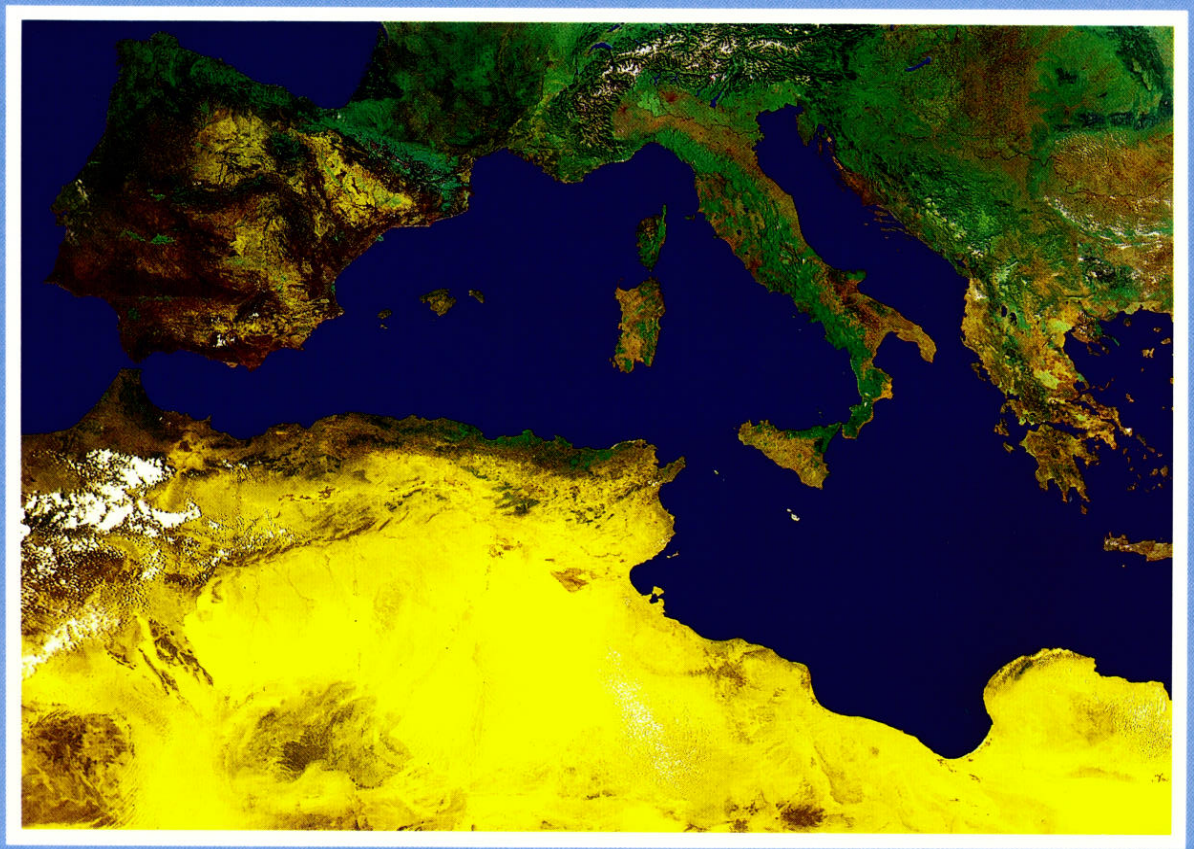
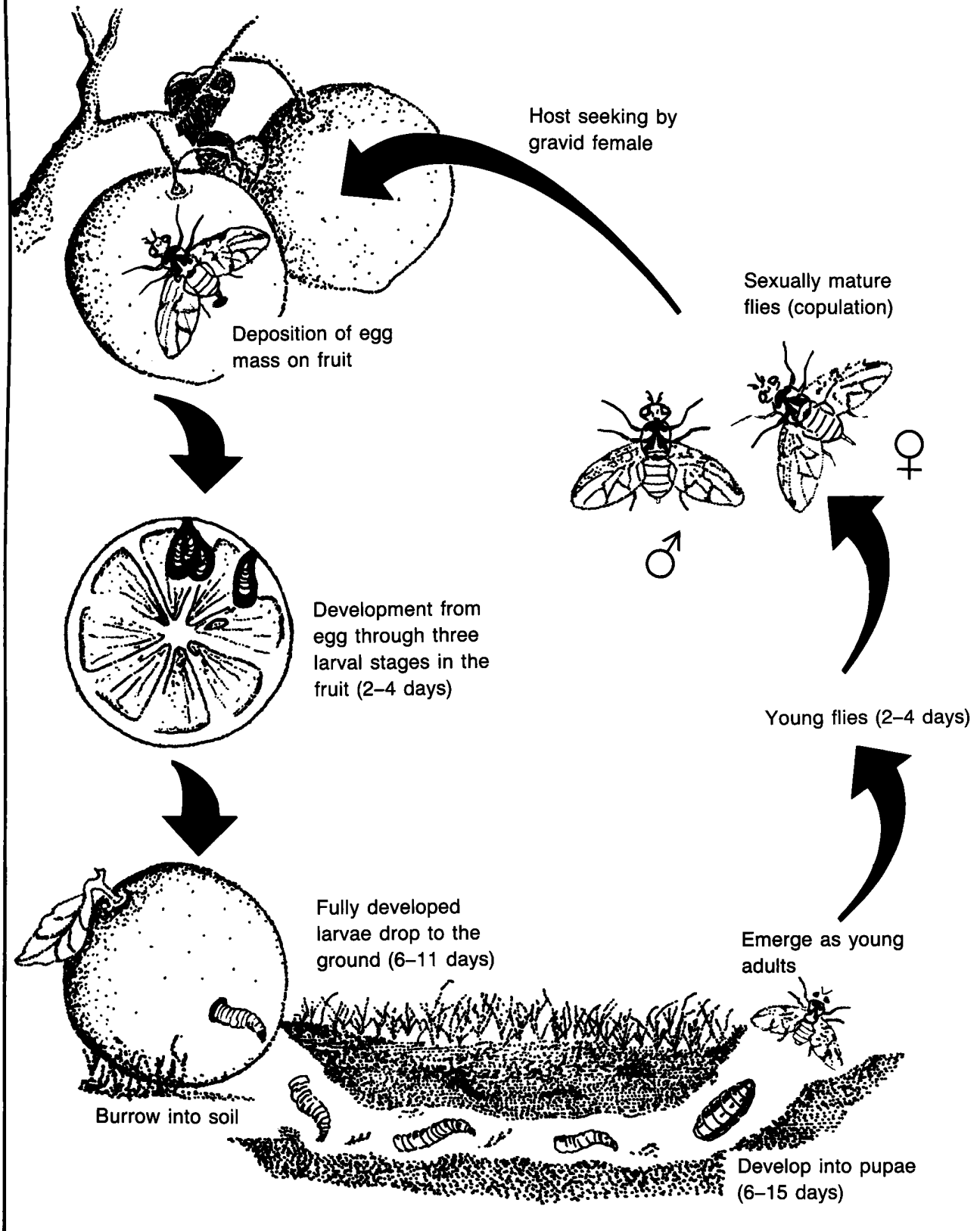
A Programme for the Eradication of the Mediterranean Fruit Fly from Algeria, the Libyan Arab Jamahiriya, Morocco and Tunisia

Prepared by an Expert Group
Vienna, 30 March – 10 April 1992

International Atomic Energy Agency



LIFE-CYCLE OF THE MEDITERRANEAN FRUIT FLY



A PROGRAMME FOR THE ERADICATION OF THE MEDITERRANEAN FRUIT FLY FROM ALGERIA, THE LIBYAN ARAB JAMAHIRIYA, MOROCCO AND TUNISIA

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INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

The Mediterranean fruit fly (medfly) exacts a heavy toll on the people of North Africa. On the other hand, this pest creates an opportunity for people from within and outside this region to co-operate in an effort not only to minimize the effects of the pest, but also to transform the horticultural industries of these countries and to raise the standards of nutrition and standard of living of people in this region. In order to determine whether a feasible strategy to deal with this pest problem could be devised, the Governments of Algeria, the Libyan Arab Jamahiriya, Morocco and Tunisia requested assistance from the IAEA Department of Technical Co-operation and from the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. Accordingly, Technical Co-operation Project RAF/5/013 was initiated in 1988. It was planned in three phases. The objective of Phase One was to survey the extent of infestation of the medfly, to elucidate its seasonal development in relation to the fruiting of its various host plants, and to measure and assess the economic losses caused by the pest. The objective of Phase Two is to conduct some pilot trials of technologies designed to deal with the problem in order to train a cadre of specialists and to modify the technology as appropriate. Finally, the objective of Phase Three is to implement a programme throughout the region to cope effectively with the pest.

Economic assessments have shown that two management strategies were far superior to the current approach involving uncoordinated individual efforts, or to the area wide use of baits. These superior strategies are the: (a) area wide *management* of the pest, short of actual eradication, based on use of the sterile insect technique and (b) *eradication* of the pest from the region.

The *eradication* strategy is being recommended to the Governments because of its: (1) favourable economic returns on investment, (2) unparalleled environmental safety, (3) institution of permanent quarantines to shield crop production generally from the incursion of dangerous exotic pests and diseases, and (4) requirement for training people in a wide array of technical and leadership skills and abilities. In order to permit the Governments to examine in detail the requirements of eradication, and to provide a 'blueprint' for its implementation, should they choose to do so, an Expert Group was assembled to develop this document. This report can serve as the foundation for Phase Three.

EDITORIAL NOTE

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EXECUTIVE SUMMARY

The Mediterranean fruit fly (medfly) is the only fruit fly of economic importance affecting a large number of fruits and vegetables in the Maghreb (Algeria, Libyan Arab Jamahiriya, Morocco and Tunisia). The medfly causes losses of fresh fruit and vegetables in this region of about US $90 million each year. Therefore, eradication of this pest at this time would be very beneficial. Technologies are available to eradicate the medfly which will have no significant negative environmental impacts, and they can be used to accomplish eradication at reasonable cost.

The eradication programme, hereafter called MAGHREBMED, will result in increased production of fruits and vegetables with enhanced quality and value. This can translate into increased economic benefits for producers and consumers, as well as better nutrition for the population at large.

Also, the eradication of the medfly will facilitate the diversification of agricultural production and the development of other industries needed to meet the demands of increased growth. Increased employment opportunities will be created for harvesting, grading, packing and marketing of products for domestic use and export. The attendant crop diversification will provide economic incentives for support of the programme by growers, other beneficiaries and governments.

In the absence of the medfly, growers can drastically reduce the application of insecticides and produce commodities and specialty crops at less cost. Reduced usage of insecticides will be beneficial to the environment. Moreover, when the production area is free of the medfly, no post-harvest treatments against this pest will be required to export the fruits and vegetables that serve as its hosts.

Pest management and eradication programmes are much more effective and economical when applied on a regional basis, rather than by individual countries. Inherent in such publicly supported programmes is the development of phytosanitary and other infrastructures needed by a properly developed fruit and vegetable industry. An appropriate phytosanitary infrastructure greatly benefits other plant and animal protection programmes. Such organized programmes also provide significant educational and employment opportunities, as well as facilitating the introduction of new technologies.

Species of economically important fruit flies other than the medfly occur in many other countries outside the Maghreb. They would create major difficulties if they were introduced into the Maghreb. Therefore, the plan of operations includes quarantine actions needed to prevent the introduction and establishment of these damaging exotic pests.

The MAGHREBMED programme is estimated to require ten years and cost US $319 million. It will begin in the Libyan Arab Jamahiriya and proceed westward to the Atlantic Ocean until completed. Although eradication activities will begin in the Libyan Arab Jamahiriya, the other countries, Algeria, Morocco and Tunisia, will concurrently conduct a variety of pre-eradication activities in preparation for the eradication phase.

Prior to achieving eradication throughout the Maghreb, other strategies, including certified pest-free areas, can be implemented. The latter would permit the export of traditional host crops without the need for post-harvest commodity treatment. Such areas would also permit the production of non-traditional fruits and vegetables. Certified pest-free areas can be established in those Maghreb countries that have areas of production that can be kept free of reinfestation at reasonable cost, and that can meet the phytosanitary requirements of importing countries.

This report outlines the procedures available to eradicate the medfly from the Maghreb with primary reliance on the use of sterile flies. A large fruit fly rearing facility, of modular design, must be constructed in the Mediterranean Basin and outside the Maghreb to produce and sterilize flies.

The available survey procedures are adequate to guide the eradication programme, as well as to detect other species of fruit flies that may be introduced. This will facilitate the early eradication of the medfly and provide a basis to promptly eradicate incipient infestations of other species shortly after they have been introduced.

National organizations must adopt and enforce quarantines to control the movement of fruit fly hosts through commercial shipments, personnel baggage, express carriers and the mail. Quarantines

are needed to support the eradication programme and to prevent re-introduction of the pest into areas from which it has been removed.

Funding for the programme should be contributed in part by the participating countries, but a significant portion of the funding must be provided by donors. It is anticipated that an executing agency will be designated to provide executive leadership in working with donors and participating countries.

Technical support for MAGHREBMED should be provided by the IAEA's Department of Technical Co-operation, the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and the Agency's Laboratory at Seibersdorf (the latter two part of the IAEA's Department of Research and Isotopes), the FAO's Agriculture Department, by medfly specialists from research and action agencies in various countries, as well as by regional plant protection bodies, such as the European Plant Protection Organization (EPPO) and the North American Plant Protection Organization (NAPPO). The MAGHREBMED programme will include methods development and mission oriented research, so that programme operations may be continuously improved.

The participating countries must agree to eradication protocols that provide for an autonomous organizational structure to conduct the programme. Expatriate employees will provide initial programme guidance and training of the national staffs. As the medfly is cleared from a given zone or country, the expatriate staff would move to the next zone or country, leaving the trained national staff to finalize the eradication phase and conduct post-eradication activities.

The trained nationals would then assume leadership in their country to more effectively manage plant and animal pests through the utilization of advanced plant protection and quarantine technology.

Because of the extremely effective eradication technologies available and the limited time required to achieve eradication, it is essential that market development activities be initiated at the same time as eradication. Indeed, since market development takes much longer than eradication, it would be desirable to undertake market development activities as soon as a decision is reached to undertake a programme of eradication, but in any case prior to the beginning of a programme of eradication or of area wide pest management.

Factors that could retard the progress of the programme of eradication, or result in failure to achieve eradication in all areas of the Maghreb, include the following:

- Insufficient funding or delays in allocation of funds, so that work cannot be accomplished according to plan;
- Use of insufficient numbers of traps, or failure to operate trapping networks in strict accordance with the protocols provided in the trapping manuals;
- Insufficient numbers of high quality sterile flies, or interruptions in their distribution according to plan;
- Failure to conduct eradication activities/measures according to schedule, or failure to apply them properly and over a sufficient time period (usually equivalent to four life-cycles of the medfly);
- Inadequate enforcement of quarantine measures;
- Inadequate training of programme personnel;
- Failure to take timely and adequate measures prior to the campaign and throughout its duration to secure the goodwill and co-operation of the industry, the general public and special interest groups, including environmentalists;
- Acts of war, natural catastrophes, or other disasters that cannot be controlled by personnel conducting the eradication campaign.

This report includes a fairly detailed plan of work and a recommended budget.

INTRODUCTION

The presence of the Mediterranean fruit fly (medfly), *Ceratitis capitata*, in the Maghreb region of North Africa (Algeria, Libyan Arab Jamahiriya, Morocco and Tunisia) causes serious economic losses in the production and marketing of host fruits and vegetables and compromises efforts to accomplish regional agricultural diversification and development.

Eradication technology, which utilizes the sterile insect technique (SIT), has been used successfully to remove this pest from several countries. The topographical and climatological conditions in the Maghreb make eradication of this fly much easier than in countries with large contiguous areas of host plants that are generally infested.

This programme was developed by the IAEA's Department of Technical Co-operation and the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, of the IAEA's Department of Research and Isotopes, in response to requests from the Maghreb countries for technical assistance. Acquisition of donor support and implementation of the operational programme to eradicate this pest might be accomplished most appropriately through the leadership of an executing agency. Supporting research, development and technical backstopping should be provided and co-ordinated by the Department of Technical Co-operation, by the Department of Research and Isotopes, through programmes in Vienna and at the Agency's Laboratory in Seibersdorf, near Vienna, and by the FAO Department of Agriculture.

PROBLEM

The medfly is a major problem in Algeria, the Libyan Arab Jamahiriya, Morocco and Tunisia. Its presence causes great economic losses to the fresh fruit and vegetable industries. These losses have been conservatively estimated to be in excess of US $90 million annually. However, these estimates do not adequately address the potential loss in the export market. In summary, this pest causes increasing production costs, restricts the development of the agricultural industry, greatly limits export opportunities and affects the cost and availability of commodities on the domestic market.

The region lacks a well developed plant protection and quarantine infrastructure that is needed to prevent the introduction and spread of new pests. The countries remain a fertile ground for other damaging sterile flies and a wide spectrum of other species of harmful organisms. If the import of infested host material continues to be allowed, eradication of the medfly from this region is at risk of not continuing to be a viable option. Consequently, pesticide applications and post-harvest commodity treatments will become increasingly needed.

With the passing of time, attitudes toward extensive pesticide usage are becoming progressively more critical. Indeed, the time may come when crop protection practices that require regularly repeated pesticide usage are no longer acceptable. Environmental protection and pollution are becoming dominant concerns of society.

BACKGROUND

The medfly has spread from its origin in sub-Saharan Africa throughout its current range on that continent, into the Mediterranean Basin and Europe, into Australia, Hawaii and other Pacific islands, and into South and Central America. Fruit fly introductions into Australia, Chile, Japan, Mexico and the mainland of the United States of America are eradicated when detected. New Zealand is the only major fruit producing country that has been able to totally exclude sterile flies by means of a strict quarantine.

Under warm (summer) conditions, the medfly's life-cycle is completed in 18–33 days. Newly emerged flies must feed on proteinaceous materials in order to become sexually mature and mate. The female deposits one to ten eggs per puncture and lays an average of 300 eggs in a life-span of one to two months. Eggs hatch in about three days. The larvae feed throughout the fruit for ten days and leave it during the third stadium to pupate in the soil. The pupal stage lasts about ten days (for further details, see Annex 1).

The medfly has been reported to be associated with more than three hundred different hosts; however, the list of preferred hosts is restricted to about thirty-five species. These highly preferred hosts, including apricot, peach, nectarine, plum and some varieties of citrus such as sweet orange, mandarin and sour orange, as well as guava, loquat, fig and mango, are usually heavily attacked. The list of hosts that are subject to attack, including those commercially produced, is extensive and all must be regulated to prevent the artificial spread of the pest (see Annex 2).

The medfly is so destructive that pest controls must be applied to produce its preferred host crops. In the USA, it is estimated that if the medfly became established, losses would average US $831 million annually. For that reason, millions of dollars and thousands of tonnes of insecticide are occasionally expended to eradicate new introductions. In the Maghreb, a conservative estimate of the financial loss is US $60–87 million per year. In addition, about US $10 million in pesticide treatment costs are also incurred. These figures for the Maghreb do not adequately take into consideration the crop losses associated with restrictions on potential export crops other than citrus, stone fruits and pome fruits, nor those economic losses associated with production, harvesting and marketing.

Isolated infestations of the medfly have been eradicated many times in Australia and the USA using pesticide bait sprays alone or in combination with sterile fly releases. Also, the medfly has been eradicated using sterile medflies as the primary eradication procedure. In areas of Central America, Mexico and the USA, the use of the sterile insect technique (SIT) has been proved to be a successful and reliable eradication technology.

OBJECTIVES

The primary objective of this programme is to eradicate the medfly from Algeria, the Libyan Arab Jamahiriya, Morocco and Tunisia. In these countries, the medfly can be found in the relatively narrow band of arable land that is bordered by the Mediterranean Sea in the north and the Atlas Mountains or Sahara Desert in the south. Elimination of this pest from North Africa will obviate the need for the costly and extensive application of insecticides, will improve the quality of the commodities currently attacked by the fly, and provide opportunities for future agricultural growth, development and diversification. Further, the eradication of this pest in the Maghreb will stimulate other countries in the Mediterranean Basin to consider a similar course of action.

The immediate objectives are to provide the needed resources and expertise to facilitate successful eradication of the fly from its present range. The eradication programme will begin in the Libyan Arab Jamahiriya and proceed westward to Morocco. This effort will involve training personnel in each country to develop and maintain a quarantine programme that will control pest movement, establish a surveillance system to detect the pest and use integrated control/eradication methods that include SIT and limited bait treatments.

Achievement of the long range objective, the successful eradication of the medfly, will make it unnecessary for the commercial producers of fruit and host vegetables to resort to multiple applications of insecticides to protect their crops. Without insecticide usage, the product can qualify as organically grown and command a higher price. The reduction of insecticides and better product quality will benefit the producer and consumer.

Removal of the medfly will make it cost effective to produce a variety of different products that cannot be grown with the medfly present. This diversification will promote self-sufficiency and a better quality of life. Exports will be able to move to foreign destinations without further treatment for the medfly.

The training and development of the national work forces will allow national plant protection and quarantine organizations to protect their countries from the introduction of other injurious plant and animal pests/diseases. If other pests are accidentally introduced, these countries will also have the expertise and infrastructure in place to eliminate or manage these new pests.

PRIOR OBLIGATIONS AND PREREQUISITES

The *donors* should:

- Secure the required funds and provide them in a timely fashion to allow the appropriate execution and administration of the programme.
- Agree to the establishment of an autonomous organization to manage the eradication programme at the regional and national levels.

The *participating countries* should:

- Agree to the establishment of an autonomous organizational structure to administer and execute the programme.
- Agree on the overall programme plan/strategies and the use of regionally approved programme manuals governing operational procedures.
- Provide to the MAGHREBMED programme management the authority to employ, direct and discharge personnel, enter into contracts for services, and make purchases of supplies, materials and equipment.
- Provide candidates for the position of Co-Director of the eradication field programme, who will assist the Director of the field programme in carrying out eradication activities in accordance with the approved plan.
- Permit, and strongly expedite, the tariff-free import of supplies, materials, equipment and other associated items needed to conduct the programme.
- Provide the authority needed to utilize airport facilities (i.e. landing rights), foreign civilian aircraft and to conduct low altitude flight operations if it is deemed necessary to accomplish programme objectives.
- Provide assurance that programme operations can proceed without interference from activities associated with military manœuvres, national holidays, etc.
- Provide for the establishment of office facilities, field offices, packing–distribution facilities and associated storage areas for programme equipment, material and supplies.
- Permit the use of approved communications technologies, i.e. telephones, radios/radio navigation, positioning equipment and computer mapping capabilities.
- Provide to the plant protection and quarantine authorities of importing countries a list of those potential host crops that the Maghreb countries wish to export. Similarly, provide a list of plant pests other than the medfly that may be associated with the export crops. These lists must be furnished at least one year in advance of the proposed export dates. This will allow the recipient country time to review the list and make a pest risk assessment.
- One year prior to the initiation of the eradication programme in a given country: (a) have fully operational a survey programme for the medfly and other exotic fruit flies in accordance with the regional plan, and (b) adopt and enforce quarantine regulations needed to support the programme within the country and prevent introductions of fruit flies from other areas (see Annex 3).

The *programme* must:

— Execute the eradication campaign according to the operational plan, and associated protocols and manuals, and accomplish the necessary changes required to successfully implement all field operations.
— Effectively communicate with the members of the Executive Board, the technical advisors and other interested groups to inform, update and communicate pertinent information concerning the administration and execution of the programme.

OPERATIONAL WORK PLAN

PEST DATA

The medfly is widely distributed over approximately 220 000 km^2 of rainfed or irrigated arable land of the Maghreb countries. Pockets of infestation occur in low rainfall areas where water from other sources is available. Primary hosts include many commercial fruit species which grow in an area of approximately 3440 km^2. They include many varieties of citrus, stone fruits (apricot, peach, plum, nectarine, etc.), pome fruits (apples, pears, quince, etc.) and other traditionally cultivated fruits such as pomegranates and figs.

The estimated levels of infestation in these fruits typically range from 10 to 30%. The stone fruit and citrus are more heavily infested than are pome fruits. Infestation levels of other hosts are usually very low, except some preferred non-commercial wild hosts.

The medfly is present year round in most of the commercial fruit growing area. The climatic conditions and a continual source of preferred and alternative hosts make this possible. The seasonal population fluctuation of the medfly follows a somewhat similar pattern in all the Maghreb countries. The density of the population starts increasing slowly from early April to the beginning of June, when a rapid increase occurs, with the fly densities reaching very high levels in July. These levels persist until mid-August and then they start to decrease. During September and October, population densities stay at moderate levels, only to increase again to reach a second peak during November and December. Then the population density drops drastically and remains low from January to March.

ERADICATION STRATEGY

Appropriate plans and activities must be developed and thoroughly executed in order to achieve timely eradication of the medfly from the Maghreb.

The eradication process will progress through three sequential phases: pre-eradication, eradication and post-eradication. In order to successfully carry out these broad phases, several basic activities must be accomplished. These activities include training, public information, trapping, quarantine and other regulatory operations, insecticidal bait treatments, the mass production and distribution of sterile flies, etc.

Some of these activities must be initiated early in the programme, in the pre-eradication phase, and will have to be accomplished before other activities can be started. Other activities will be conducted concurrently and serve to complement the achievement of the overall strategy (these phases and activities are described in Annexes 4–6).

The eradication programme should be initiated in the Libyan Arab Jamahiriya and progress westward in predetermined operations until the medfly has been eradicated from Morocco (Annex 6). Sections of land (blocks) encompassing an area of up to 5000 km^2 will be used as the basic unit for conducting the eradication activities. As eradication is achieved in any one block, the adjacent block is then subjected to the same eradication operation.

One reason for initiating the programme in the eastern part of the Maghreb is that the Libyan Arab Jamahiriya has had a very successful experience with the eradication of the New World Screwworm, *Cochliomyia hominivorax*. This programme was based on the use of SIT and intensive regulatory measures (national and international quarantines). This highly effective programme has produced many trained personnel and has sensitized government officials and the public to regulatory actions. In addition, the topography of the Libyan Arab Jamahiriya offers certain advantages not present in other locations. The surface area occupied by hosts of the medfly is quite limited and can be successfully isolated after eradication. This relative isolation will also allow programmed management to refine field activities, so that they function efficiently under more diverse conditions elsewhere in the region.

While the primary eradication activities begin in the Libyan Arab Jamahiriya, other field activities, that must be accomplished in advance of eradication efforts, will be started in the other countries, i.e. public relations, training, quarantine, survey, etc. This does not preclude any participating country from establishing certified fly-free areas. If this approach is supported by the growers, this could facilitate eradication of the medfly ahead of schedule.

Eradication will be achieved through an integrated programme. A bait spray will be used against high populations to lower them so that a high ratio of sterile to wild medflies may be achieved. Even against low level populations, one bait spray application will be made to eliminate the long lived gravid females that do not mate with sterile males. The bait spray is a mixture of the insecticide malathion and a hydrolysed protein. The bait is applied at low volumes and in the form of droplets which are designed to be environmentally safe. These treatments are very effective in reducing medfly populations to manageable levels. This activity will be followed by weekly releases of sexually sterile medflies to eliminate reproduction of any remaining adults in the population. This procedure has been used successfully in many countries during the last twenty years.

Implementation of the eradication strategy must be timed to take full advantage of the biotic and abiotic factors that impact the fly population. Maximum efficiency from SIT is achieved when initial releases are timed to coincide with naturally occurring low fly population densities.

Application of SIT in accordance with the eradication plan will require the availability of at least 750 million sterile medflies per week for the entire duration of the programme. Therefore, it is necessary to build facilities capable of producing such large numbers of flies (for detailed information, see Annex 7).

The eradication effort will rely on a well developed and functional surveillance system. This detection activity consists of the operation of a large number of traps in a trapping network. The network will be operational before any eradication activities are carried out. Regional and national detection activities will be used to determine fly locations and densities. Fruit collection will complement the adult trapping network and can be used to determine if immature stages of the medfly are present.

Continual monitoring of selected areas within the eradication programme will facilitate the eradication and establishment of medfly-free areas. This will provide industry with the opportunity to develop certified fly-free zones, a system that can allow the movement of fruit from these areas into export channels without resorting to the otherwise required post-harvest commodity treatments.

High priority must be given to the regulatory controls and activities that are undertaken to support the eradication programme. In order to prevent the reinfestation of fly-free areas, there must be appropriate control of movement of host material within the countries, as well as the operation of international quarantines that prevent the import of infested plant material into each country. It must be stressed that the regulation of potentially infested commodities constitutes the primary method of preventing the artificial spread and reinfestation by the medfly.

Public acceptance and co-operation are absolutely essential to a successful eradication effort. Therefore, a public information campaign will be needed to secure such vital support. This activity must be started ahead of field activities to inform, educate and engender support for the programme. Potential problems can be averted by advising the public in advance of anticipated actions. Emphasis

must be placed on national involvement and individual participation. The information programme should stress the many benefits of eliminating the fly from the country and from the region.

A complex programme requires an efficient management system to handle the large volume and wide variety of data and information. Through the use of computers and data management systems (software), it is possible to use current data/information to accomplish timely and effective management. This technology can be expanded to facilitate the production of technical reports , inter- and intra-programme correspondence, and mapping.

Key personnel will require training prior to initiating field activities. Some of the training will have to be accomplished at outside institutions. This first group of trainees can then serve as trainers for others in the work force. The training will focus on methods of pest control, quality control, detection and quarantine technologies, the process of eradication, etc. Some formal instruction will also be given to introduce and inculcate the plant protection and quarantine concepts and principles that support regulatory activities Recurrent training, including 'refresher courses', should be provided when appropriate.

An operational programme of this magnitude will require the support of mission oriented research aimed at increasing programme effectiveness and reducing costs. However, most pure and basic research should be conducted outside the MAGHREBMED programme.

Long term protection from reinvasion will come from a strong institutional commitment to regulation quarantines and the consistent and effective use of eradication technologies.

PUBLIC INFORMATION

Public information activities are indispensable and will greatly influence the degree of difficulty encountered in the field in the implementation phase. In order to inform, educate and engender support for MAGHREBMED, public information activities will be started during the pre-eradication phase and well ahead of the field activities. Once started, public information activities will continue throughout the programme. Some public information activities will also serve to support the post-eradication phase. While the public information unit will have an established campaign to address anticipated needs, it will have to be prepared at all times to adjust its focus to issues that are unforeseen.

The public information unit will be responsible for managing the inquiries of the media, for responding to requests for information by the public and for providing support to programme personnel preparing oral or written presentations. Also, this unit will co-ordinate the development and production of programme posters, publications and other educational materials that will be used to strengthen ongoing activities. Some informational activities will be carried out in co-operation with local government officials to ensure that the product is appealing and meets the needs of the public while building support for programme actions.

TRAINING

Training is one of the most important elements of the programme. A formalized training activity will facilitate the development of a permanent plant protection and quarantine infrastructure at the national level. It will also promote regional interaction, since training will be accomplished on a national and regional basis. The infrastructure that is a consequence of the eradication programme will ensure that the countries in the region remain free of injurious pests. A higher standard of quarantine protection will promote more beneficial involvement with other countries and a more productive, sustainable and profitable agricultural industry in each of the host countries.

The basic methods and procedures that will be needed to initiate the programme will have to be introduced to a nucleus of the work force before starting actual field activities. This group can then train others in the technologies as the field programme becomes operational. The 'on-the-job' (OJT)

training will be augmented by the curriculum of a regional training centre. Structured courses will be designed to provide more formal training in plant protection and quarantine concepts, principles, procedures and activities. Advanced training will include all phases of field operations, as well as management and supervisory concepts.

A training centre for conducting these activities should be located in the region to better accommodate travel and reduce costs. At a later date this centre could also serve an expanded region, such as much of the Mediterranean Basin.

RESEARCH AND DEVELOPMENT

Some mission oriented research and development (R&D) must be conducted to continuously improve operational procedures and technologies. This type of R&D can and should be conducted by or within the programme. It should be initiated during Phase 2 and continued through Phase 3.

Of course not all lines of potentially beneficial R&D can be conducted within the MAGHREBMED programme. Thus, to assure effective international co-ordination and planning and the conduct of well targeted R&D, it is recommended that the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture place increased emphasis on enlisting the co-operation of the Western Hemisphere Fruit Fly Working Group, which is associated with the International Organization of Biological Control (IOBC), as well as that of various national organizations that conduct relevant basic and applied research.

MANAGEMENT STRATEGIES LEADING TO ERADICATION

There are several strategies that may be used to improve the efficiency of medfly control in the Maghreb. The use of any of these strategies would benefit the general public by improving the nutritional quality of diets. They would benefit the growers by reducing costs, benefit the environment by requiring much less use of insecticides, and benefit governments through significant improvements in plant protection activities. The use of all available strategies will contribute to the eradication of the medfly from the region.

The strategies considered to be of benefit to the Maghreb and the benefits accruing from their use are given below.

Area Wide Management of the Medfly Without the Use of SIT

The management of medfly populations on an area wide basis using insecticides would improve the effectiveness of the control treatments and reduce costs. In a co-ordinated area wide approach, much less insecticide would be needed than by the unco-ordinated treatments made by individual growers. The addition of quarantine actions to prevent the entry of new plant pests, including other fruit flies, would further improve plant protection in the area.

Medfly-Free Areas

The establishment of medfly-free areas would be the next logical step in an area wide pest management programme. With an area wide treatment programme, additional bait sprays can be applied to eliminate the medfly from specific geographical areas. The addition of quarantines to prevent re-entry of the medfly and survey activities to assure that complete elimination has been accomplished would be cost effective since crops produced in medfly-free areas can be exported without the need for post-harvest treatments. For many hosts there are no post-harvest commodity treatments available as a basis for export. Therefore, the use of medfly-free areas allows the production

and export of fruits and vegetables that are hosts of the medfly. Crop diversification and export are powerful economic incentives for adopting the medfly-free area concept. In many instances it is not practical to use the SIT in medfly-free areas because of the costs of obtaining and releasing flies, and of examining trapped flies to assure that sterile flies are released rather than native flies (see Annex 8).

Maghreb Wide Use of SIT for Pest Management

If some or all Maghreb countries would agree to area wide pest management, SIT could be used in conjunction with other pest management measures to reduce or prevent crop losses. Limited use of bait sprays — one or two well timed applications — would be required to protect preferred hosts. Through ongoing research and development, other techniques such as the release of parasites (e.g. *Dichasmimorpha longicaudata)* or bait sprays using *Bacillus thuringiensis (Bt)* may be developed to replace insecticides now in use.

A pest management programme using SIT as the primary measure would be beneficial to the environment because much less insecticide would be required. Also, for maximum benefit, such a programme should be supported by quarantines to prevent reinfestation of cleared areas and the introduction of new pests.

Maghreb Wide Eradication Using SIT

If some or all of the Maghreb countries would implement an area wide pest management strategy involving use of SIT, the logical and most effective approach would be to improve the programme to the extent required to eradicate the medfly. Eradication provides the greatest benefits because (a) no insecticides would be needed on an ongoing basis against the medfly, and as a consequence biological control of other crop pests by natural enemies would become much more effective; (b) crops now grown and non-traditional crops that could be produced in the area could then be exported without post-harvest commodity treatments; and (c) the infrastructure for protecting the health of plants and animals could be focused to deal more effectively with pest and disease problems.

PRECAUTIONARY MEASURES AND MONITORING

This section deals in general terms with precautions that need to be considered in planning and conducting the programme to manage/eradicate the medfly in the Maghreb.

The eradication programmes will involve primarily the release of sterile insects (SIT) in combination with bait sprays when needed to reduce wild fly populations to the level that permits eradication by releasing sterile flies. On the basis of emerging technological developments, it may be possible to reduce native fly populations through the use of techniques other than insecticide application, such as the release of parasites or the use of *Bacillus thuringiensis* in bait sprays.

The medfly eradication programme may involve treatments in areas inhabited or transited by threatened or endangered species. This should not present a problem, since the sterile insect release method is the primary technology and it will be supported by the limited use of large droplet bait sprays.

In programmes to eradicate medflies that have been conducted to date, fish kills in naturally occurring water systems have not presented a problem. Nevertheless, it is highly desirable to avoid contamination of water with insecticides to the extent possible.

The primary problems which may be encountered in connection with the use of malathion bait sprays relate to potential impacts on honey bees, other pollinating insects, and on beneficial parasites or predators.

No long term serious impacts have been noted involving parasites and predators of agricultural pests. Additional studies would be desirable to determine how best to proceed if medfly infestations involve crops on which pest control is attained primarily through the use of biological control organisms. Eradication has been accomplished utilizing bait sprays applied to alternate strips. This approach is effective because of the attractiveness and residual activity of large droplet bait sprays. In selecting options, consideration must be given to the insecticide applications made by growers to control or manage pest species other than the medfly.

Strategies employed to protect honey bees include covering hives during application of bait sprays, timing applications to avoid periods when bees are actively foraging in treatment areas, and temporarily moving bee colonies from treatment areas, etc. The options selected will depend on many factors, including the size of the area under treatment as well as the number of bait sprays that must be used.

Regardless of the extent of previous field observations and research studies dealing with non-target organisms, it is suggested that efforts be made to co-operatively conduct monitoring studies, particularly for programmes involving new geographical areas. Monitoring studies on non-target organisms, including biocontrol agents in infested areas previously involved in bait sprays, may not need to be as extensive as those in areas where poison baits are being used for the first time. In any case, emphasis should be given to involving various concerned groups, such as ornithologists, entomologists and environmental organizations in studies on programme impacts on non-target species. Through such co-operative studies, as well as through increased emphasis on developing modified or new pest suppression strategies, it should be possible to develop information and approaches needed to eradicate the medfly without causing serious impacts on non-target species in areas where this is of special concern.

QUALITY CONTROL

Control of the work being done, or quality control (QC), will be accomplished at every level of management and supervision. Quality control is a practice that each employee should adopt to better execute daily activities. Indeed, quality is every employee's business and responsibility.

The supervision and review of operational activities will be carried out according to predetermined standards of measurement and performance that will be outlined in operational manuals and protocols (see Annex 9). The documents will be used by the medfly and supervisory personnel to execute each activity and review the quality of the results. Deviations from accepted standards, procedures, methods (process control) or expected results will necessitate review, and often correction. Changes in operational activities may be made only with the prior approval of the supervisor when there is an action or situation that obviously would result in a negative consequence if activities were not modified immediately.

While each operational unit will have to conduct quality control activities to ensure that the development of the product or the activity is proceeding as planned, a separate QC unit will be responsible for overall quality control of the programme. This operational unit will review survey, chemical control, quarantine and SIT activities. This review responsibility will make it necessary for QC personnel to be familiar with all phases of the operations and the technologies involved. They will interact with employees in the operations sections and with the supervisors of these field units to inform them of their findings. The QC group will be directly responsible to the field programme Director, as are the other unit supervisors.

Quality control checks will also be applied to the sterile flies as they are produced in the off-site factory. The flies will be produced according to specific standards and will have to meet these standards before puchase and use in the programme. A representative of the programme's QC unit will be on-site at the mass rearing facility to monitor quality.

ORGANIZATION AND MANAGEMENT

As shown in the MAGHREBMED organizational chart (Annex 10), the Executing Agency will establish at its headquarters a programme that will be known as MAGHREBMED. This programme will have the primary responsibility for the management and the administration of all activities pertaining to the eradication programme. Thus, it will direct overall activities and provide management co-ordination for the operations being conducted in each country. MAGHREBMED will have a director, one or two technical officers, an information officer and an administrative officer.

A Programme Co-ordination Committee will be established by the Executing Agency. This Committee will deal with matters of policy and resource acquisition, but not with management issues, which will be the responsibility of the Executing Agency. The Committee will assist the Executing Agency in securing international and national support for accomplishing programme activities. It can assist in resolving complex political problems that may jeopardize the accomplishment of programme goals.

The Programme Co-ordination Committee will be chaired by a high ranking official in the Executing Agency. Representatives of donors, participating governments and participating international organizations will be members of this Committee. Also, the field programme Director and the four Co-Directors will be members. They will provide the Committee with general programme information and progress reports, and will inform it concerning conditions or situations that may affect the programme.

MAGHREBMED will appoint a Technical Advisory Committee to provide technical oversight of all activities and operations that have a bearing on the effectiveness and efficiency of the overall effort to eradicate the medfly from the Maghreb. Typically, the Technical Advisory Committee will conduct reviews and report to MAGHREBMED every six months. However, it will function as needed to avert or solve problems.

The organizational structure of the MAGHREBMED field programme will resemble that of an emergency action programme. It will require separate and distinct institutional arrangements and operational procedures. Therefore, a separate, well defined and functional organization must be established. Although temporary in nature, it must have sufficient autonomy and authority to conduct the programme as dictated by operational plans, protocols and field conditions. Although the MAGHREBMED field programme will be solely responsible for conducting the eradication programme, it must receive the required support from all involved parties to accomplish the goal of the programme.

The MAGHREBMED field programme will have the right to receive and disburse funds, the authority to employ and discharge personnel, the ability to purchase supplies and equipment, enter into contractual arrangements, and conduct field activities under the delegated authority granted to it by each host government. Personnel can be seconded to the eradication programme from the host government on a temporary basis to augment the administration and implementation of programme activities.

This programme will be led and managed by an expatriate field programme Director and by four field programme Co-Directors, i.e. one national from each country. Each participating country will have a national programme organizational structure that, once it has been decided to proceed with eradication, will be responsible and subordinate only to the MAGHREBMED field programme Director. While some activities, such as external quarantine, will be accomplished by officials of each country, the personnel will be responsible to him. Each MAGHREBMED field programme Co-Director is a vital and key participant in the national MAGHREBMED field programme of the country where eradication is undertaken. He or she serves as the local interface with government personnel, policy making officials, the impacted industry and others.

Because of the large sizes of infested areas and the finite supply of sterile flies, eradication operations will be undertaken in one country at a time, block by block. While eradication activities are under way in a given block, preparatory activities must be undertaken in the adjacent block. When eradication has been accomplished in a given block, post-eradication activities must be implemented in this block.

At this same time, eradication activities are shifted to the next block that has been prepared for them. In this manner the programme will progress across the Maghreb. This will require commensurate adjustments in the responsibilities of each Co-Director.

The operations positions (quarantine, chemical control, SIT, data processing, data analysis, quality control of operations, etc.) will be supervised by a team of expatriates and nationals. The nationals will be trained to manage and supervise the activities. They will replace the expatriates when the latter are moved to other blocks and/or countries as eradication proceeds.

The far flung nature of the programme will require that one of the technical officers at MAGHREBMED headquarters must work full time in assisting the MAGHREBMED field programme Director to co-ordinate activities across the entire Maghreb. Both MAGHREBMED headquarters and the MAGHREBMED field programme must adequately support the diverse activities with administrative and technical expertise to ensure that the national organizations receive the required management support and guidance, technical oversight and review.

At the same time, a conscious effort must be made to accomplish technology transfer. This will enable the national personnel to acquire the most advanced plant protection and quarantine concepts, principles, procedures and methodologies. These advances can then be incorporated into the existing national infrastructures for plant protection. This will promote long term protection of the pest-free status achieved through programme efforts.

ESTIMATED BUDGET

An estimated budget summary by year and by expenditure for the nine years of the programme is shown in Tables I and II. The estimates are as accurate as could be made in April 1992. Refinement of the figures must await the results of the pilot trials of Phase 2 and the finalization of plans for the mass production of sterile flies.

PROGRAMME BENEFITS

ENVIRONMENTAL PROTECTION

Fruit flies are of concern to agriculture because of the damage inflicted to most host crops and because the mere presence of the pest precludes access to the most lucrative markets. Damage (losses during production and marketing) is sufficiently extensive that a marketable crop cannot be produced unless the growers apply pesticides.

In most cases fruit fly control programmes conducted by individual growers involve the use of small droplet sprays with or without baits. Often formulations and even the insecticide selected by growers are more toxic to non-target organisms than the malathion bait sprays employed in public programmes. Area wide supervised management programmes afford less damage to the environment than programmes conducted independently by growers because they require a smaller quantity of insecticide per hectare. Eradication usually is achieved after programme operations have covered three to nine life-cycles of the pest — usually lasting three to nine months. After eradication, no treatments are needed for the medfly, neither for crop protection nor to permit export. Accordingly, in less than one year, an area wide programme has a very beneficial effect on the environment.

Insecticides used by growers to control the medfly are toxic to the honey bee. Area wide management/eradication programmes using SIT as the primary tool are more benign environmentally, since a maximum of four applications of malathion bait are needed to reduce medfly populations to a level that can be eradicated with sterile males. If an area wide programme relies on insecticides alone,

TABLE I. ESTIMATED BUDGET BY YEAR (ALL SUMS OF MONEY IN UNITED STATES DOLLARS)

Activity	Total	Year								
		1	2	3	4	5	6	7	8	9
1. Mass rearing	93 009 667									
1.1. Facility[a]	20 000 000	20 000 000	0	0	0	0	0	0	0	0
1.2. Maintenance and spares	9 946 667	333 333	343 333	915 556	915 556	1 716 667	1 430 556	1 430 556	1 430 556	1 430 556
1.3. Mass rearing operations	63 063 000	6 825 000	7 029 750	7 029 750	7 029 750	7 029 750	7 029 750	7 029 750	7 029 750	7 029 750
2. Training	6 403 445	1 576 981	1 160 208	417 675	1 160 208	417 675	1 160 208	417 675	46 408	46 408
3. Public information	9 486 218	1 689 623	1 392 249	556 900	1 392 249	556 900	1 392 249	556 900	556 900	1 392 249
4. Data management	5 691 731	1 013 774	835 350	501 210	835 350	501 210	835 350	501 210	501 210	167 070
5. Research and development	11 076 356	2 054 581	1 615 009	1 058 109	1 058 109	1 058 109	1 058 109	1 058 109	1 058 109	1 058 109
6. Surveillance	25 897 872									
6.1. Trapping	14 126 112	1 528 800	1 574 664	1 574 664	1 574 664	1 574 664	1 574 664	1 574 664	1 574 664	1 574 664
6.2. Fruit sampling	11 771 760	1 274 000	1 312 220	1 312 220	1 312 220	1 312 220	1 312 220	1 312 220	1 312 220	1 312 220
7. Bait sprays	38 808 000	4 200 000	4 326 000	4 326 000	4 326 000	4 326 000	4 326 000	4 326 000	4 326 000	4 326 000
8. Sterile fly releases	67 567 500	7 312 500	7 531 875	7 531 875	7 531 875	7 531 875	7 531 875	7 531 875	7 531 875	7 531 875
9. Field operation expenses	9 477 680	1 200 759	1 236 781	913 315	1 236 781	913 315	1 236 781	913 315	913 315	913 315
10. Quarantine	26 327 148	4 186 209	2 380 746	3 412 403	2 380 746	2 380 746	3 412 403	2 380 746	2 380 746	3 412 403
11. MAGHREBMED HQ	15 940 915	2 331 679	2 401 630	1 601 087	1 601 087	1 601 087	1 601 087	1 601 087	1 601 087	1 601 087
12. MAGHREBMED field programme HQ	5 085 584	644 309	663 639	490 072	663 639	490 072	663 639	490 072	490 072	490 072
13. Emergency plan	3 944 706	0	138 065	138 065	138 065	205 125	205 125	205 125	205 125	2 710 013
Total	318 716 822	53 368 749	31 054 634	28 892 015	30 269 414	28 728 530	31 883 130	28 442 419	28 071 152	32 108 907

[a] Must be constructed in the 'Preliminary Phase'.

TABLE II. ESTIMATED BUDGET BY EXPENDITURE (ALL SUMS OF MONEY IN UNITED STATES DOLLARS)

Activity	Total	Expenditure							
		Personal services	Duty travel	Contracts	Operating expenses	Supplies and materials	Furniture and equipment	Premises or improvement	Grants and fellowships
1. Mass rearing	93 009 667								
1.1. Facility[a]	20 000 000	0	0	0	0	0	11 000 000	9 000 000	0
1.2. Maintenance and spares	9 946 667	0	0	4 973 333	0	0	4 973 333	0	0
1.3. Mass rearing operations	63 063 000	16 081 065	315 315	13 243 230	9 459 450	23 963 940	0	0	0
2. Training	6 403 445	2 689 447	1 664 896	192 103	128 069	128 069	384 207	0	1 216 655
3. Public information	9 486 218	3 604 763	948 622	2 845 865	284 587	1 138 346	664 035	0	0
4. Data management	5 691 731	2 447 444	341 504	512 256	0	569 173	1 707 519	0	113 835
5. Research and development	11 076 356	1 882 981	332 291	8 861 085	0	0	0	0	0
6. Surveillance	25 897 872	1 553 872	1 165 404	517 957	9 064 255	5 697 532	7 769 362	129 489	0
6.1. Trapping	14 126 112	847 567	635 675	282 522	4 944 139	3 107 745	4 237 834	70 631	0
6.2. Fruit sampling	11 771 760	706 306	529 729	235 435	4 120 116	2 589 787	3 531 528	58 859	0
7. Bait sprays	38 808 000	1 164 240	1 164 240	9 702 000	5 433 120	17 851 680	2 716 560	776 160	0
8. Sterile fly releases	67 567 500	2 027 025	675 675	43 918 875	3 378 375	4 054 050	2 027 025	11 486 475	0
9. Field operation expenses	9 477 680	7 676 921	1 042 545	0	568 661	189 554	0	0	0
10. Quarantine	26 327 148	7 898 144	2 106 172	1 579 629	2 369 443	6 581 787	3 159 258	1 316 357	1 316 357
11. MAGHREBMED HQ	15 940 915	11 158 641	2 550 546	318 818	956 455	318 818	637 637	0	0
12. MAGHREBMED field programme HQ	5 085 584	3 559 909	813 693	101 712	305 135	101 712	203 423	0	0
13. Emergency plan	3 944 706	0	414 983	829 966	2 074 915	829 966	0	0	0
Total	318 716 822	61 744 452	13 535 886	87 596 830	34 022 465	61 424 627	35 242 359	22 708 482	2 646 847

[a] Must be constructed in the 'Preliminary Phase'.

safeguards, such as removal of honey bees from the eradication zone, must be considered. The details of safeguarding bees must, therefore, be considered carefully when designing area wide management programmes.

In programmes designed to prevent entry or to eradicate new species of fruit flies, consideration should be given to the potential impact of new species on existing biota and possible ecological disruptions, including the impact on beneficial species.

MARKET POTENTIAL AND DEVELOPMENT

The presence of the medfly in the Maghreb significantly limits the export of fresh fruits and vegetables to lucrative markets. Elimination or management programmes for the medfly would permit producers to export host crops currently in production, as well as provide an opportunity to produce and export other hosts that can be grown in the Maghreb. This would provide an incentive for national crop diversification projects. The increased production of more diversified and better quality fruits and vegetables would lead to increased local consumption and to more varied diets.

The marketing of potential export crops requires the development of techniques for proper grading and packing, adequate transportation facilities and equipment, and other procedures involved in product export. Many countries have little or limited experience in the international marketing of many fruit fly host materials. The development of such procedures opens new employment possibilities, in addition to those related strictly to crop production. Thus, with the development of export markets, there would be an increase in the availability of 'hard currency', jobs with good pay and general economic well being in the area.

Because of the extremely effective eradication technologies available and the limited time required to achieve eradication, it is essential that market development activities be initiated at the same time as eradication. Since market development takes much longer than eradication, it would be desirable to initiate such work as soon as a decision is made to initiate an eradication/management programme.

INFRASTRUCTURE DEVELOPMENT

Surveys

Surveys must be conducted to eradicate/manage the medfly. Very effective detection survey procedures are available for many other economically important fruit flies. Although the degree of effectiveness varies between species, sufficiently effective tools are available to develop baseline data and guide eradication/management technologies for many species. Surveys must be conducted to provide for early detection of new outbreaks of the medfly, to delineate infestation limits and to monitor the effectiveness of eradication procedures. Although different survey procedures are involved for other plant and animal pests, the principles involved are similar. Therefore, an effective survey programme for the medfly would be a helpful model in designing programmes for other pest species.

Plant Quarantine

Adequate quarantine controls must be in place and enforced to prevent new medfly invasions. Regulations within the country are essential also to control movement of the medfly in support of the eradication programme. Quarantine procedures used for the medfly can be used as a basis for amending/developing regulations for use in preventing the introduction and spread of other plant and animal pests. The employment of effective quarantine procedures in developing and developed countries is to the mutual benefit of all countries concerned with pests of agriculture. The extent to which

strong quarantines are put into effect and enforced will have a direct impact on the number of pest introductions that are likely to occur in other countries. Also, when assessing quarantine regulations of a country that wishes to export, officials of importing countries normally give consideration to all plant protection activities of the exporting country.

Pest Management/Eradication

The general procedures employed to eradicate or manage the medfly can be used for other economically important fruit flies. For many other pest species, adequate rearing and release of sterile flies (SIT) have been perfected, whereas for others this technology is not yet available. The use of protein hydrolysate bait/malathion sprays (bait sprays) is effective for most if not all economically important fruit flies. It is not economically feasible to rear and sterilize sufficient numbers of flies to overwhelm heavy native medfly populations. Therefore, the use of SIT usually requires bait sprays or other management techniques to reduce fly population levels to the point that sterile males can effect eradication. For some species, it may be possible to use SIT alone due to natural reduction in fly populations at certain times of the year. Also, inundative release of parasites to reduce fly populations appear to be effective for some species and can be used in lieu of bait sprays.

Specific technologies for different fruit flies and other pests may vary, but the management/eradication technologies used against the medfly will be of value in designing pest management programmes for other plant/animal pests.

EDUCATION AND TRAINING

The technical expertise needed for fruit fly management programmes (including the medfly) may or may not be available in each country. Regardless of the extent to which it is available, management/eradication programmes offer employment opportunities. Training received in such programmes will be of value to other agricultural pest management programmes. Additionally, many employees of fruit fly programmes have been inspired to attend schools and obtain more technical training. This is beneficial not only to the employees, but to their countries as well.

RESEARCH

This report is not intended to deal with the basic need for effective research to guide fruit fly eradication or pest management programmes. It goes without saying that research findings make it possible to develop and further improve management/eradication programmes. Also, research organizations benefit from such programmes as action programme managers identify specific needs for new knowledge or technology and demand research support to improve programme effectiveness. The resultant interrelationships are mutually beneficial to the two groups and they benefit agriculture and the general public.

ECONOMIC AND SOCIAL BENEFITS

As has been briefly discussed, successful management/eradication of economically important fruit flies should:

— Provide opportunities for crop diversification;
— Provide for increased employment to produce and market high quality crops for local consumption and export;

— Result in better diets within the country;
— Expand export markets for agricultural produce;
— Improve and stabilize governmental programmes for plant and animal pest management;
— Improve the economic stability and profitability of agriculture and related industries;
— Lead to improvements in educational programmes.

RISKS

The MAGHREBMED eradication programme is a complex and involved undertaking. It could fall short of total eradication if it is not conducted in accordance with the work plan. Some factors that could prevent the attainment of complete eradication of the pest from all of the region are:

— Insufficient funding, or funds not received in a timely manner to allow the work to be accomplished according to the work plan;
— Use of insufficient quantities of traps, or traps are not operated in accordance with programme protocols (trapping manual);
— Insufficient numbers of high quality sterile flies;
— Eradication activities/measures not applied routinely and/or inappropriately through the required number of life-cycles;
— Inadequate quarantine enforcement;
— Inadequate training of programme personnel;
— Inadequate public relations campaign to obtain co-operation from the industry, the general public and special interest groups, such as environmentalists;
— Acts of war, natural catastrophes, or any other disaster outside the control of programme personnel.

Annex 1

LIFE-CYCLE

The life-cycle is temperature dependent. Egg and larval development, and adult activity are influenced by the air temperature, whereas pupal development depends on the soil temperature. The minimum temperatures at which no measurable development takes place are 11°C in soil and 9.7°C in air (fruit). An empirical model has been developed that uses air temperature data to predict the duration of all life stages. Experience with this model has shown that a temperature of 12°C measured in the air can be used as a developmental threshold for all stages. The number of degrees accumulated for a given period of days above the developmental threshold for a life stage are called day-degrees and 346°C day-degrees must be accumulated to complete a life-cycle.

The procedure for calculating the number of day-degrees in a given period and the number of generations of the medfly that developed during that period are as follows:

(1) For each day add the minimum air temperature to the maximum air temperature and divide by 2 to obtain the average daily air temperature;
(2) Subtract the developmental threshold temperature (i.e. 12°C) from the average daily temperature. The result is the number of degrees for that particular day;
(3) For all of the days in the period find the sum of day-degrees;
(4) Now divide the total number of day-degrees by the number of day-degrees required to complete one life-cycle. The result is the number of generations of the insect that developed during the period.

Technical programme plans require a minimum of three life-cycles of trapping with negative results following the last application of bait spray or sterile fly release before eradication can be considered to have been accomplished. Therefore, it is essential that the temperature threshold model be used during the winter or cooler part of the year.

Averages and variations in the life-cycle are as follows:

— *Adults*. The normal life expectancy is up to two months, but may be up to ten months under cool conditions; the female deposits one to ten eggs in an oviposition puncture in the peel of the fruit, but other females may oviposit in the same puncture; only one mating is required, but adults may mate more than once; females lay an average of 300 eggs in a lifetime, but individuals may lay up to 800; females may wait to lay until favourable maturing hosts are available and they do not lay when temperatures drop below 17°C; newly emerged adults are not sexually mature and must feed on a proteinaceous substance to reach sexual maturity; the pre-oviposition period varies depending upon environmental conditions, but the minimum period is two days.
— *Larvae*. They feed throughout the fruit and go through three larval stadia requiring an average of 6–11 days before leaving the fruit. By jumping the larvae find a suitable location to burrow about 1–2.5 cm deep into the soil to pupate. Occasionally, larvae pupate in debris.
— *Pupae*. This stage lasts 6–15 days and allows the insect to survive in unfavourable conditions. Survival is substantial in the soil between 9° and 34°C, but in very wet soil or below 30% relative humidity, the mortality rate is high.

Annex 2

HOSTS THAT SHOULD BE REGULATED

Although the medfly has reportedly been associated in varying degrees with more than 350 species of plants, *only* those species which are hosts (i.e. plant species that provide for reproduction of the medfly) should be included in the list that should be regulated. This list contains about 75 species.

The regulated hosts should include:

Common name	Scientific name
Akee	*Blighia sapida*
Almond with husk	*Prunus dulcis = (P. amygdalus)*
Apple	*Malus domestica*
Apricot	*Prunus armeniaca*
Argan tree	*Argania spinosa = (A. Sideroxylon)*
Avocado	*Persea americana*
Barbados cherry	*Malpighia glabra* and *M. punicifolia*
Bourbon orange	*Ochrosia elliptica*
Calamondin orange	*Citrofortunella mitis*
Canistel	*Pouteria campechiana*
Ceylan gooseberry	*Dovyalis hebecarpa*
Chanar	*Geoffroea decorticans*
Cherimoya	*Annona cherimola*
Cherry (sweet and sour)	*Prunus avium, P. cerasus*
Citron	*Citrus medica*
Coffee	*Coffea arabica*
Custard apple	*Annona reticulata*
Date	*Phoenix dactylifera*
Dwarf papaya	*Carica quercifolia*
Fig	*Ficus carica*
Gourka	*Garcinia xanthochymus*
Grape	*Vitis vinifera*
Grapefruit	*Citrus paradisi*
Guava	*Psidium guajava*
Hawthorn	*Crataegus* spp.
Hog plum	*Spondias mombin*
Japanese persimmon	*Diospyros kaki*
Japanese plum	*Prunus salicinia*
Jocote	*Spondias purpurea*
Kei-apple	*Dovyalis caffra*
Kiwi	*Actinidia chinensis*
Kumquat	*Fortunella japonica*
Lemon (except commercially grown Eureka, Lisbon and Villa Franca cultivars)	*Citrus limon*
Lime	*Citrus aurantiifolia*
Litchi	*Litchi chinensis*
Longan	*Euphorbia longana*
Loquat	*Eribotrya japonica*

Mandarin orange (tangerine, clementine)	*Citrus reticulata*
Mango	*Mangifera indica*
Mock orange	*Murraya paniculata*
Mombin	*Spondias* spp.
Mountain apple	*Syzygium malaccense* = *(Eugenia malaccensis)*
Natal plum	*Carrissa grandiflora* and *Terminalia chebula*
Nectarine	*Prunus persica*
Olive	*Olea europea*
Prickly pear/Opuntia cactus	*Opuntia* spp.
Papaya	*Carica papaya*
Passion fruit	*Passiflora edulis*
Peach	*Prunus persica*
Pear	*Pyrus communis*
Pepper, Tabasco pepper	*Capsicum annuum* and *C. frutescens*
Pineapple guava	*Feijoa sellowiana*
Plum	*Prunus americana*
Pomegranate	*Punica granatum*
Pomiform guajava	*Psidium guajava*
Pond apple	*Annona glabra*
Prune	*Prunus domestica*
Pummelo (Shaddock)	*Citrus maxima*
Pyriform guajava	*Psidium guajava*
Quince	*Cydonia oblonga*
Rose apple	*Syzygium jambos* = *(Eugenia jambos)*
Sapodilla	*Manilkara zapota*
Sour orange	*Citrus aurantium*
Spanish cherry (Brazilian plum)	*Eugenia braziliensis* = *(E. dombeyi)*
Spanish plum	*Spondias mombin*
Star apple	*Chrysophyllum* spp.
Strawberry guava	*Psidium cattleianum*
Sugar apple	*Annona squamosa*
Sugarpalm	*Arenga pinnata*
Surinam cherry	*Eugenia uniflora*
Sweet orange	*Citrus sinensis*
Tomato (pink and red ripe)	*Lycopersicon esculentum*
Tree tomato	*Cyphomandra betacea*
Tropical almond	*Terminalia catappa*
Walnut with husk	*Juglans* spp.

Annex 3

QUARANTINE REGULATIONS

Adequate quarantine regulations must be established by each participating state or country. The regulations must be enforced (not through the use of voluntary green door/red door procedures) to prevent spread within the country in support of fly-free areas and the eradication programme. Also, such regulations must apply to and be enforced to cover commercial importations of host products and, just as importantly, other avenues or means of entry such as mail, express packages and by people who often carry hosts in hand luggage or in checked luggage.

The quarantine regulations and enforcement procedures must be similar throughout the Maghreb and, in fact, internationally. Also, sufficient follow-up monitoring must be accomplished to assure compliance.

The quarantine must:

- Provide definitions as needed;
- List those host products that are subject to regulation;
- List areas (states/countries) known to be infested with the medfly;
- List certification procedures, including treatments, that may be or are available to allow movement of host products from infested areas, or states/countries of non-infested areas;
- Provide for the issuance and attachment of certificates or limited permits when necessary to prevent spread;
- Provide for agreements, and cancellation thereof, which outline procedures to be followed by individuals or concerns which handle or transport host products;
- Provide for the prompt imposition and collection of fines for willful, intentional or repeated violations of quarantine regulations.

Annex 4

WORK PLAN

A. Perform analysis

1. Cost-benefit.
2. Technical feasibility.
3. Environmental study.
4. Funding sources.
5. Define support of Maghreb host countries.

B. Mass rearing

1. Construction of factories.
2. Implementation of mass rearing.

C. Staffing

1. Recruitment of personnel.
2. Selection of key staff.
3. Selection of local technicians.
4. Administrative personnel.

D. Training

1. Key staff accomplish data management, surveillance, bait sprays, sterile fly releases, quarantine and public information training.
2. In-service training for local personnel.

E. Public information

1. Region wide information campaign for the eradication project (international quarantines, benefits, etc.).
2. Local public information campaign (domestic quarantines, sterile fly releases, bait sprays, etc.):
   - — Libyan Arab Jamahiriya,
   - — Tunisia,
   - — Algeria,
   - — Morocco.

F. Data management systems

1. Purchase of computer equipment.
2. Development of custom designed computer programs for mass rearing, field operations, quarantines and administrative evaluations.

G. Research and development

1. Refinement of sterile male mass rearing technology.
2. Quality control methodologies.
3. Key factors of medfly population dynamics in the Maghreb region (spatial and temporal distribution).
4. Refinement of operational procedures for the Maghreb area.
5. Refinement of eradication processes.

H. Establishment of the organization and infrastructure to conduct the eradication programme

1. Programme headquarters (HQ) and regional infrastructure.
2. Development of operational manuals and quarantines, as well as administrative protocols.
3. National programme HQ.
4. Reinforcement of national programme HQ:

   — Libyan Arab Jamahiriya,
   — Tunisia,
   — Algeria,
   — Morocco.

I. Surveillance system

1. Complete delimiting medfly surveys in all countries.
2. Intensive survey/monitoring in countries under suppression/eradication:

   — Libyan Arab Jamahiriya,
   — Tunisia,
   — Algeria,
   — Morocco.
3. Detection trapping for medfly and other exotic fruit flies:

   — Libyan Arab Jamahiriya,
   — Tunisia,
   — Algeria,
   — Morocco.

J. Control actions

1. Aerial and ground bait sprays in countries under suppression/eradication:

   — Libyan Arab Jamahiriya,
   — Tunisia,
   — Algeria,
   — Morocco.
2. Aerial and ground sterile fly releases in countries under suppression/eradication phases:

   — Libyan Arab Jamahiriya,
   — Tunisia,
   — Algeria,
   — Morocco.

K. Regulatory actions

1. Declaration and enforcement of international quarantines:

   — Libyan Arab Jamahiriya,
   — Tunisia,
   — Algeria,
   — Morocco.
2. Declaration and enforcement of domestic quarantines to support free areas and eradication.
3. Establishment/strengthening of domestic and international checkpoints:

   — Libyan Arab Jamahiriya,
   — Tunisia,
   — Algeria,
   — Morocco.

L. Eradication programme

1. Evaluations:

   — Technical,
   — Administrative.

2. Successful eradication declaration:

   — Libyan Arab Jamahiriya,
   — Tunisia,
   — Algeria,
   — Morocco.

3. Contingency plan.

Annex 5

WORK PLAN TIME FRAME

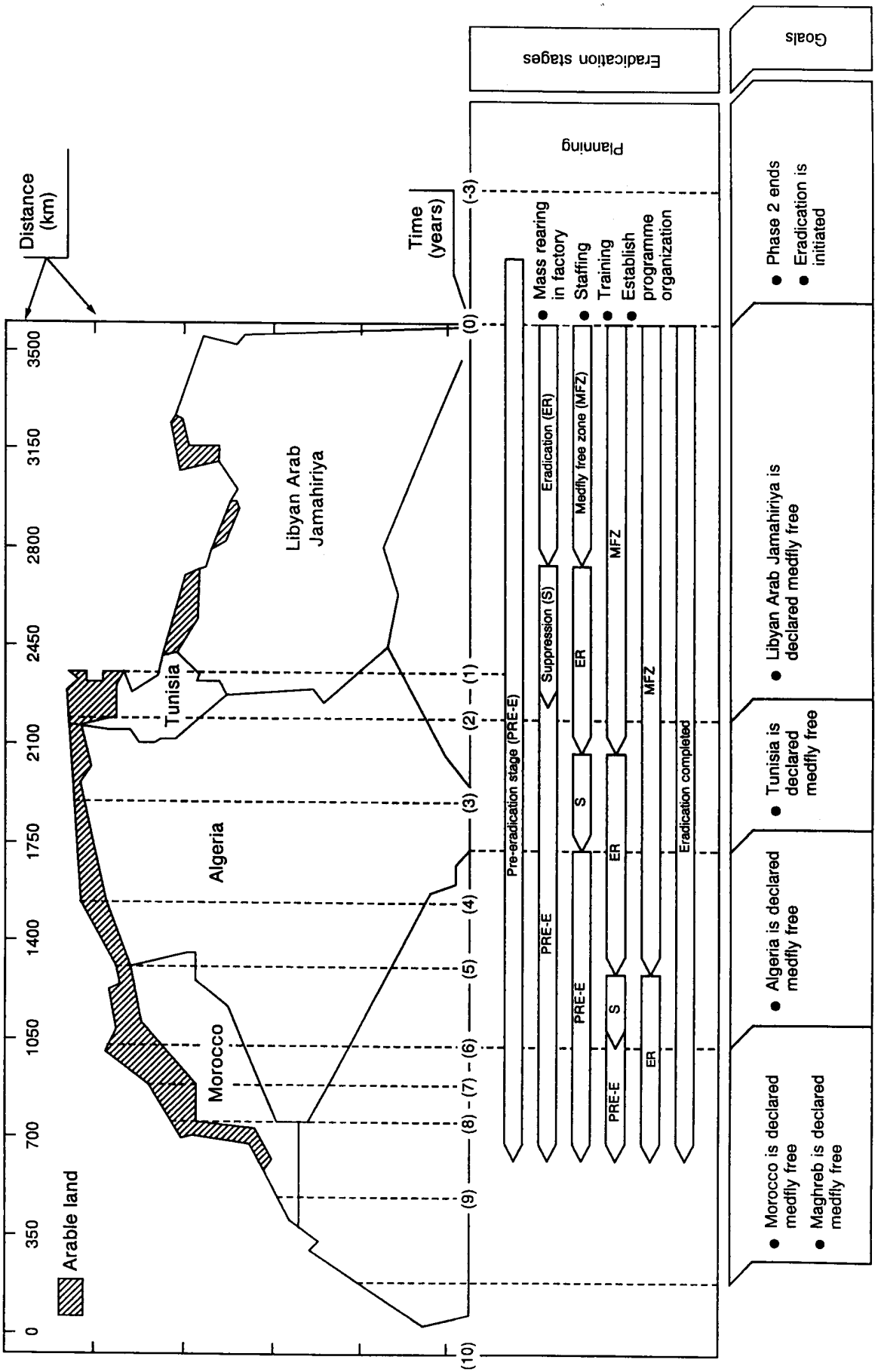
Activities	Phase 2			Phase 3									
	1	2	3	1	2	3	4	5	6	7	8	9	10
A. Analysis													
(1) Cost-benefit			*	*	*	*	*	*	*	*	*	*	*
(2) Technical feasibility			*	*	*	*	*	*	*	*	*	*	*
(3) Environmental study			*	*	*	*	*	*	*	*	*	*	*
(4) Funding sources			*	*	*	*	*	*	*	*	*	*	*
(5) Define support of Maghreb host countries	*	*	*	*	*	*	*						
B. Mass rearing													
(1) Construction of factories		*	*										
(2) Implementation of mass rearing			*	*	*	*	*	*	*	*	*	*	*
C. Staffing													
(1) Recruitment of personnel	*	*	*	*	*	*	*	*	*	*	*	*	*
(2) Selection of key staff	*	*	*	*	*	*	*						
(3) Selection of local technicians	*	*	*	*	*	*	*	*	*	*	*	*	*
(4) Administrative personnel	*	*	*	*	*	*	*	*	*	*	*	*	
D. Training													
(1) Key staff accomplish data management surveillance, bait sprays, sterile fly releases, quarantine and public information training			*	*	*	*	*	*	*	*	*	*	*
(2) In-service training for local personnel of participating countries	*	*	*	*	*	*	*	*	*	*	*	*	*
E. Public information													
(1) Region wide information campaign for the eradication project (international quarantines, benefits, etc.)	*	*	*	*	*	*	*	*	*	*	*	*	
(2) Local public information campaign (domestic quarantines, sterile fly releases, bait sprays, etc.)													
— Libyan Arab Jamahiriya	*	*	*	*	*	*							
— Tunisia		*	*	*	*	*	*						
— Algeria				*	*	*	*	*	*	*			
— Morocco					*	*	*	*	*	*	*	*	

Activities	Phase 2			Phase 3									
	1	2	3	1	2	3	4	5	6	7	8	9	10
F. Data management systems													
(1) Purchases of computer equipment	*	*	*	*	*	*	*	*	*	*	*		
(2) Development of custom designed computer program for mass rearing, field operations, quarantines and administrative evaluations	*	*	*	*	*	*	*	*					
G. Research and development													
(1) Refinement of sterile male mass rearing technology	*	*	*	*	*	*	*	*	*	*	*	*	*
(2) Quality control methodologies	*	*	*	*	*	*	*	*	*	*	*	*	*
(3) Key factors of medfly population dynamics in the Maghreb region (spatial and temporal distribution)	*	*	*	*	*	*	*	*	*				
(4) Refinement of operational procedures for the Maghreb area	*	*	*	*	*	*	*	*	*	*	*	*	*
(5) Refinement of eradication processes				*	*	*	*	*	*	*	*	*	
H. Establishing the organization and infrastructure to conduct the eradication programme													
(1) Programme HQ and regional infrastructure			*	*	*	*							
(2) Development of operational manuals including quarantines		*	*	*	*								
(3) National programme HQs			*										
(4) Reinforcement of national programme HQs													
— Libyan Arab Jamahiriya			*	*	*								
— Tunisia				*	*								
— Algeria						*	*	*	*				
— Morocco										*	*	*	
(5) Preparation of administrative protocols			*	*	*	*							
I. Surveillance system													
(1) Complete medfly surveys in all countries	*	*	*	*									
(2) Intensive survey/monitoring in countries under suppression/eradication													
— Libyan Arab Jamahiriya			*	*									
— Tunisia				*	*	*							
— Algeria						*	*	*					
— Morocco									*	*	*	*	

Activities	Phase 2			Phase 3									
	1	2	3	1	2	3	4	5	6	7	8	9	10
I. Surveillance system (cont.)													
(3) Detection trapping for medfly and other exotic fruit flies													
— Libyan Arab Jamahiriya	*	*	*	*	*	*	*	*	*	*	*	*	*
— Tunisia	*	*	*	*	*	*	*	*	*	*	*	*	*
— Algeria	*	*	*	*	*	*	*	*	*	*	*	*	*
— Morocco	*	*	*	*	*	*	*	*	*	*	*	*	*
J. Regulatory actions													
(1) Declaration and enforcement of international quarantines:													
— Libyan Arab Jamahiriya			*	*									
— Tunisia					*	*							
— Algeria						*	*						
— Morocco								*	*				
(2) Establishment/strengthening of domestic and international checkpoints													
— Libyan Arab Jamahiriya				*	*	*	*	*	*	*	*	*	*
— Tunisia				*	*	*	*	*	*	*	*	*	*
— Algeria							*	*	*	*	*	*	*
— Morocco								*	*	*	*	*	*
K. Eradication actions													
(1) Aerial and ground bait sprays in countries under suppression/eradication:													
— Libyan Arab Jamahiriya				*									
— Tunisia					*								
— Algeria						*							
— Morocco								*	*				
(2) Aerial and ground sterile fly releases in countries under suppression/ eradication:													
— Libyan Arab Jamahiriya				*									
— Tunisia					*	*							
— Algeria						*	*	*					
— Morocco									*	*	*	*	
L. Post-eradication activities													
(1) Evaluations													
— Technical				*	*	*	*	*	*	*	*	*	
— Administrative				*	*	*	*	*	*	*	*	*	
(2) Successful eradication declaration													
— Libyan Arab Jamahiriya					*								
— Tunisia							*						
— Algeria									*				
— Morocco													*
(3) Review contingency plan					*	*	*	*	*	*	*	*	*

Annex 6

ERADICATION PHASES



Annex 7

STERILE INSECT PRODUCTION-DELIVERY

Laboratory

Irradiation Source

— Cobalt or caesium available.
— System desired will dictate source option.
— US/Canadian and French sources have limited capacity and are costly.
— Hussman caesium unit cost is approximately US $750 000.
— Unit must function 16 h/d.
— A plant for 500 million flies/week needs two units.
— New unit can service 200 000 pupae every 2 min.

Design

— Modular design for 500 million to 1 thousand million capacity per week.
— Manage each unit like a division of one plant.
— Two 500 million capacity modular plants adjacent?
— Optimum module size 100–500 million?
— Share some common core support resources.
— Separate management and technical support.
— Use sufficient base water chiller units.
— Decentralize HVAC (heating, ventilation, air-conditioning) delivery units.
— Allow for 100% failure of air delivery units.
— An auxiliary power plant needed for the facility.
— Clean water source required.

Packing and Rearing

Chilled Adult

— Temporary or permanent rearing structures.
— A 3.6 m × 18 m space/room supplied with approximately 55 kW of electricity.
— The space/room volume is only 75–80% occupied.
— There are 40 000 flies per Park box.
— There are 20 000 000 flies per space/room.
— Each week the space/room will be occupied for 4 d, plus 1 d for cleanup.
— Each space/room needs 3–5 t of air-conditioning capacity.
— An auxiliary power plant needed for the facility.
— Ten spaces of 3.6 m × 18 m each will require approximately 55 kW of electricity.
— Cost for trailer of 3.6 × 18 m is approximately US $15 000.

Bag System

— Space required for 100 million flies per day.
— Each bag contains 20 000 flies.
— Five thousand bags for 100 million flies.

— Room temperature requirement is 20–24°C.
— Room humidity needs are 70–80% relative humidity.
— Flies are kept in darkness for 60 h.

Sterile Insect Release

— Use 100 000 flies/km^2 per week.
— Males and females, or males alone.
— Cost per million, 500 million capacity at US $175 per million.
— Knockdown area, 2.5 m × 13.5 m, can process five million flies per hour.
— Mobile/portable units cost US $50 000–75 000.
— Five million is one load for a distribution or 'drop' machine.
— Distribution of five million flies requires one hour of preparation time for a five person crew.
— One hour is required for preload knockdown (3.3°C).
— One hour is required for distribution at 240+ km/h (150+ mph).
— Four hours is the maximum limit that flies should be held at low temperatures.
— Limits of the number that can be distributed are flying time and equipment.
— One plane can fly about four hours daily.
— Drop machines each cost approximately US $20 000. Six drop machines will be needed for four-five aircraft.
— A single engine aircraft costs approximately US $200–300 per hour to operate.
— A light twin engine aircraft costs approximately US $500–600 per hour to operate.
— It is possible to carry 250 bags in a light single engine aircraft such as a Cessna 206.

Annex 8

REQUIREMENTS FOR PEST-FREE AREAS

Free areas are recognized by Japan, the USA and presumably by all countries that import agricultural host crops from states or countries infested with economically important fruit flies, including the medfly. Some states/countries may require that a representative of their country visit the exporting country before recognizing their proposed defined free area(s). The pest-free area designation means that importing countries will not require a post-harvest treatment of the host crop, such as fumigation, to prevent entry of the specified pest (e.g. medfly). However, the importing countries will also make a pest risk assessment that includes other quarantine pests that may be associated with the host of the pest.

In order to obtain certification or recognition of a defined pest-free area, the exporting country must:

(1) Establish and enforce quarantine regulations necessary to protect the defined free area from re-entry of the pest;
(2) Conduct an eradication programme as necessary to eliminate the pest (medfly) from the defined area(s);
(3) Conduct a detection level survey as mutually agreed to with the importing country to promptly detect any pest (medfly) that may have breached the quarantine and immediately telephone or fax information about the discovery to the importing country;
(4) Agree to report any export shipment that may be en route to or received by the importing country that may contain infestation as a result of the discovery of infestation and mutually agree with the importing country as to the remedial measures that may be used to handle such shipments;
(5) Apply mutually agreed upon procedures to eradicate the outbreak and implement any necessary restriction to prevent spread until eradication is again achieved.

Annex 9

OPERATIONAL MANUALS

Manuals should be developed to cover each phase of the operational programme. Some of the more important items that must be considered and incorporated are given below.

Sterile Insect Technique

The quality of the flies produced in the rearing facility must be checked in accordance with a quality control manual. This manual outlines the types of tests that must be accomplished to assure the production of high quality sterile flies. Such a manual is available and currently under review. The manual also outlines shipping procedures and quality tests to be performed on flies received for field use.

Survey

The purpose of this important manual is to assure that high quality surveys are conducted. The currently available parapheromone, trimedlure, attracts primarily the male medfly and immature females. If the traps are properly utilized, they can be relied upon to trap the medfly during the first generation after introduction. However, if not used in accordance with the trapping protocol, the survey may not detect the medfly in time to provide for rapid and prompt eradication. A very essential consideration is trap location. Traps should be placed in highly preferred wild or cultivated hosts during the time that the host is fruiting. It is, therefore, essential that the manual list preferred hosts and the period during which the fruit is attractive — just prior to maturity.

The type of trap that will be most effective for detection in the Maghreb will be determined based on additional tests to be conducted in the region. Recently developed information should be used in conducting these tests. Confirmation checks should also be conducted to determine the most effective trap for monitoring sterile flies.

Chemical Control

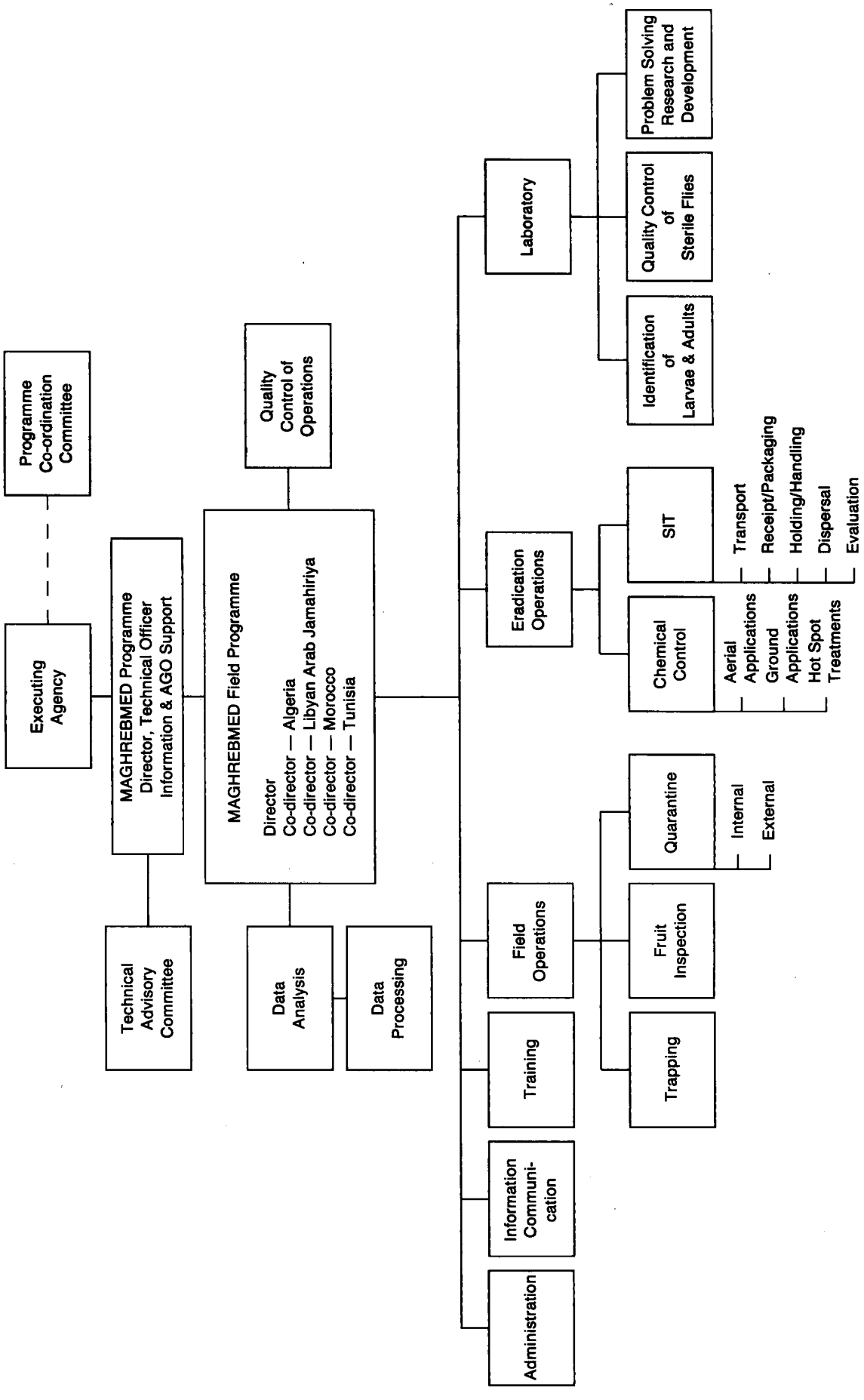
The principal elements that should be included in this manual are the (a) bait spray formulation, (b) particle size for aircraft-applied bait sprays, (c) guidance system to assure adequate spray coverage, (d) type(s) of application equipment — ground and air — and (e) spray dispersal systems.

Quarantine

The manual should refer to the host country quarantine documents and outline procedures and methods to be employed to assure compliance with regulations, including inspections at ports of arrival. Also included is the use of X ray and other procedures to detect hosts in commercial shipments, express shipments, mail, host material carried by passengers, or in checked luggage. Quarantine actions to support the eradication programme of free areas must include the regulation of the movement of economic hosts through commerce and by individuals. The procedures to be used in the levy of fines and their collection should also be outlined. Quarantines must be in operation 24 h daily, including national holidays.

Annex 10

MAGHREBMED ORGANIZATIONAL CHART



Annex 11

LIST OF EXPERTS

G.G. Rohwer	1502 Circle Drive, Annapolis, MD 21401, United States of America
G. Tween	South Central Region, Animal and Plant Health Inspection Service, PPQ, United States Department of Agriculture, 3505 Boca Chica Boulevard, Brownsville, TX, United States of America
J. Reyes Flores	Programa MOSCAMED — SARH, Apartado Postal 368, Tapachula, Chiapas, 30700 Mexico

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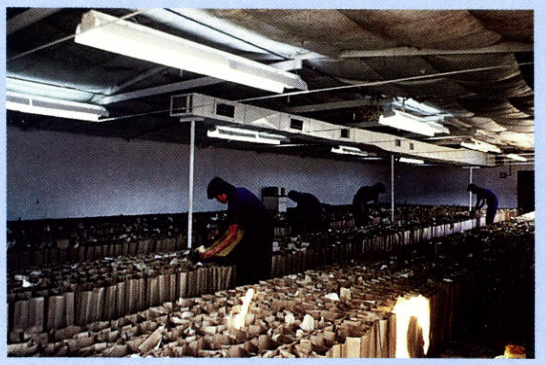
PROBLEM SOLVING

Trapping and fruit sampling

Cultural control

Bait spray application

Mass production of flies



Post-irradiation packaging

Preparation for aerial release of sterile flies

Release of sterile flies

Mating of wild and sterile flies

DAMAGE CAUSED BY THE MEDFLY