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Economic evaluation of damage caused by, and methods of control of, the Mediterranean fruit fly in the Maghreb

An analysis covering three control options, including the sterile insect technique

Report of an expert group
organized by the
Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture

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ECONOMIC EVALUATION OF DAMAGE CAUSED BY, AND METHODS OF CONTROL OF, THE MEDITERRANEAN FRUIT FLY IN THE MAGHREB

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FOREWORD

Fruit and vegetable production is a major component of the agricultural sector throughout the Mediterranean Basin. At present, however, there is a major dependence on aerial or ground insecticide applications to protect commercial crops against the Mediterranean fruit fly. This pest causes enormous damage in the more than two hundred species of fruit and vegetables it attacks. Pesticide applications are frequently required up to twelve times a year, costing large sums of money everywhere in the region.

The objective of this study was to assess for the four North African countries the economics of different pest control/eradication alternatives. It is the first study of its kind analyzing in detail three options of controlling the Mediterranean fruit fly on an area-wide basis. The study compares economic costs and benefits of control based on the continued use of insecticide sprays, with more environmentally friendly alternatives based on the Sterile Insect Technique.

Results indicate that even without including a number of important environmental costs in the study, the latter biological alternatives, when considered over the medium term, are more favourable in spite of the high initial investment. The Sterile Insect Technique used for control or eradication is, therefore, not only very attractive from the environmental point of view, but is also a feasible option from the economic point of view.

Environmentally, eradication using SIT is the most attractive alternative because the present insecticide use is not sustainable. Eradication would result in less outbreaks of new insect pests as their natural enemies will no longer be eliminated by pesticides, as well as in a drastically reduced insecticide load in the environment. The absence of the Mediterranean fruit fly would also attract renewed investment in improved fruit production and the introduction of new fruit species to the region. Finally, as medfly is a feared quarantine pest in certain countries importing fresh fruit, its absence would allow access to these important export markets.

In the future, with increasing sensitivity of the public, and with proper quantification of environmental costs, biological control methods such as the Sterile Insect Technique will become even more attractive. Already now, there is growing pressure throughout the region to reduce the use of insecticides as important trading blocks and countries that import fresh fruit are changing regulations governing the acceptable treatment and pesticide residues on fruit and vegetables.

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CONTENTS

SUMMARY

The Mediterranean fruit fly, *Ceratitis capitata*, is a major problem for fruit production in the Maghreb (Algeria, Libya, Morocco and Tunisia). Fruit growing is an important industry in the region, with an estimated value of over US $800 million per year, including considerable exports. The extent of the financial loss imposed by this pest in the region is estimated to be US $60-90 million per year, plus approximately US $7-10 million per year in insecticide treatment costs. There are additional unquantifiable losses related to (1) the lack of opportunities to export some commodities, especially stone fruits, due to high medfly infestations; (2) the need to apply additional pesticides against secondary pests, such as scale insects, mites, aphids and aleurods, as a result of the elimination of their natural enemies by insecticide applications against the medfly; and (3) the effects of the increasing insecticide use on the environment and human health. There are, therefore, two problems that require action:

- High crop losses, resulting in low yields for low input producers and lost export opportunities for high input producers.
- High pesticide use for high input producers.

Three area-wide strategies for solving the medfly problem in the Maghreb are evaluated:

- Bait suppression.
- SIT (Sterile Insect Technique) suppression.
- SIT eradication.

Technical and economic information about the three strategies was based on government statistics, a survey of losses and control in the region, past experience with medfly control in other countries, and an IAEA technical group report on the implementation of the Sterile Insect Technique (SIT) in the Maghreb.

Economic information was assembled concerning the extent of the problem and costs of these control strategies. Cost and benefit models for these control strategies applied in the Maghreb were developed to standardize the current level of production and losses among the four countries and to allow comparison of control scenarios with standard assumptions. These models can be used for several purposes: testing the outcomes of the various strategies, providing a framework to incorporate additional information that may become available for refining these evaluations, and providing guidance concerning additional economic information that needs to be collected in the future.

Cost-benefit estimations are based on a 15 year time scale determined by the longest option, SIT eradication. Each of the three control strategies requires three years of preparatory work to provide baseline ecological and environmental data. Bait suppression would then be implemented simultaneously throughout the region. SIT suppression would be implemented over a four year period. SIT eradication would require very intensive control, monitoring and quarantine efforts and would be done successively in nine zones (ranging in size from 2,500 to 5,250 km^2) over nine years. Ongoing costs and benefits are considered for a further three years after full implementation to allow a reasonable comparison of the final impact.

Three sets of criteria are considered in comparing the three strategies:

- Financial indicators.
- Environmental indicators.
- Response to market changes.

As exemplified in Figure 2, bait suppression was the most favourable strategy in terms of net present value, since it gives quick returns with little investment. However, in terms of the final annual net benefit SIT eradication would be more favourable, once it had been implemented throughout the region.

The main environmental indicator applied was pesticide use. Both SIT-based strategies reduce pesticide use whereas bait suppression increases pesticide use by an estimated 400% compared to current practice. Medfly eradication with SIT eliminates all bait sprays.

All area-wide control programmes would increase domestic consumption of fruit, contributing to the nutrition of the population.

It is expected that the importers of fruit from the Maghreb producers are likely to become more discriminating in the future, particularly to pesticide residues. Such market changes may force growers in the Maghreb to abandon insecticide-based control in order to maintain their market share. This may also affect the acceptability of bait treatments, which also interfere with attempts to control secondary pests (mostly Homopteran insects) by the release of natural enemies. Even relatively small changes in export markets could greatly reduce the economic benefits of bait suppression, if bait-treated fruit do not continue to have access to high value export markets. In that event, the SIT suppression strategy in particular, would become the most attractive strategy (based on net present value over 15 years). SIT eradication becomes the most attractive if additional markets open for fruit from certified fly-free producers.

If improved medfly control strategies are widely implemented in the Maghreb, consumers and processors would be the primary beneficiaries. Pesticide use in citrus would decrease, and losses in pome and, especially, stone fruits would be reduced. This could allow a great expansion of stone fruit production, presenting further export earning potential in the region. The cost-benefit analyses presented in the report do not take account of potential increased areas cultivated following the reduction or elimination of the medfly. Other benefits are expected with the expansion of fruit processing industries which might occur for fruit exports.

INTRODUCTION

The main objective of this report is to provide an assessment of the economic benefits of medfly management on fruit crops using the Sterile Insect Technique (SIT) in the four Maghreb countries (Algeria, Libya, Morocco and Tunisia). The report is designed to enhance the decision process of Maghreb countries and donor agencies by providing an economic foundation for using area-wide control strategies. A draft report [1] established the economic feasibility of three area-wide medfly control strategies in the Maghreb:

- Bait suppression.
- SIT suppression.
- SIT eradication.

Fruit production is a major industry in the Maghreb. Two countries (Morocco and Tunisia) have substantial fruit exports (almost entirely citrus), and all have significant domestic fresh and processed fruit consumption. For a wide range of fruit and vegetables the medfly is the only economically important fruit fly in the region and it is the primary insect pest responsible for fruit losses and pesticide residues. It is an important quarantine pest in many countries, and its presence prevents the export of some Maghreb fruits to several potential markets.

The current technique used for medfly control in the Maghreb is mainly extensive bait and cover sprays on commercial fruit crops for both export and domestic markets. This method gives good control when it is applied consistently, but it is not widely adopted by small-scale producers. It is expensive and its effect on natural enemies of such pests as white flies, scale insects, aphids and mites, may result in increased pesticide use within the Maghreb.

Medfly control using SIT has been successful in several countries (USA, Central America) and new production and sterilization techniques have been developed at the FAO/IAEA Agriculture and Biotechnology Laboratory in Seibersdorf to reduce the cost of SIT. The SIT has the potential to both reduce medfly losses and pesticide applications in the Maghreb. However, given the investments required to adopt SIT in the Maghreb, a detailed cost-benefit analysis of the likely impacts on different economic components of the fruit sectors constitutes an important input for the decision-making process.

The report includes five sections devoted to the objectives of this study. The first presents the current situation of fruit production, medfly losses and control costs in the Maghreb countries. Section 2 presents the medfly control options considered in the cost-benefit analysis. Section 3 discusses the cost-benefit techniques used to analyze medfly control in the Maghreb. Section 4 focuses on the cost-benefit results, while Section 5 discusses the implications of the results. Various appendices provide additional details.

1. THE MEDFLY PROBLEM IN THE MAGHREB

This section focuses on the magnitude and extent of medfly damage to fruit in the Maghreb and shows the level of current and future losses occurring under the prevailing control technologies.

1.1. EXTENT OF MEDFLY DAMAGE AND COST OF CHEMICAL CONTROL

Commercial citrus, pome and stone fruits are known to be susceptible to medfly with both yield and quality losses. Other traditional fruits in the Maghreb, such as pomegranates and figs, are also affected by the medfly, but these crops are less widely grown commercially. In addition, there are many non-cultivated (wild) hosts, which are of lesser economic value but cover large areas. As a result, the analysis of damage concentrates on commercial citrus, pome and stone fruits.

Three types of costs are faced by fruit producers due to medfly damage. The first cost is physical loss of crop, through fallen, rotten, culled and discarded fruit. The second cost is in lower prices from downgraded fruit in the market. The third cost is related to damage control at any stage between production and marketing. Those controls include mainly bait and cover sprays and cultural practices in the field, and post-harvest fumigation or cooling treatments for marketing higher quality grades (mainly exports). All these costs vary in different years and locations because of variability in pest levels.

Besides the costs to fruit producers identified above, fresh fruit consumers also bear costs due to high medfly pressure because of higher fruit prices and lower fruit quality resulting from reduced supply. Most Maghreb countries have high tariffs on fruit imports and are consequently protecting their domestic markets from competition. This exacerbates the price increases caused by losses in domestic supply. The fruit processing industry (mainly juice, jams and tinned fruit) may also be less competitive because of higher domestic fruit costs caused by medfly losses. Consumers respond by purchasing less fresh and processed fruits than they would if prices were lower.

Therefore, the problem posed by the medfly on susceptible fruits is related to current and future costs and opportunities forgone by fruit producers, merchants and consumers for both fresh and processed fruit. Such losses occur both in quantity and quality at production, marketing and export stages. Other costs are those related to the use of insecticides to control the medfly. These have negative environmental effects on producers and consumers and form another component of the social costs associated with current technologies for medfly control.

Estimates of medfly damage in the Maghreb were initially based on data obtained from the survey conducted in 1990 [2-6]. They were then standardized using a computer model of fruit production and medfly control in the Maghreb [1]. These estimates are then used in assessing future benefits since they reduce cross-country data inconsistencies and eliminate discrepancies due to direct use of the survey data. The current cost of controlling medfly in the Maghreb has also been estimated based on average numbers of treatments for high and low input producers in each country.

1.1.1. Fruit production losses

Fruit crops susceptible to medfly infestation in the Maghreb cover a wide range of hosts. The first set is composed of commercial fruits including citrus varieties, apricots, peaches, apples, pears, medlars and quinces. The second set includes pomegranates, figs and some other fruits (including *Opuntia* cactus) which are sold on the domestic markets but for which little information is available.

According to various authors (see bibliographical references), wild hosts of the medfly are widespread in the Maghreb. They include natural forest plants, such as argan (700,000 hectares in south-west Morocco), and other bushes and shrubs. While this natural vegetation is socially valuable (firewood, animal feeding, wild fruits, argan oil, soil preservation ...), it constitutes a reservoir of medfly. While not of direct economic value, these plants are very important ecologically and control of the medflies infesting these areas must be considered in any attempt to eradicate or suppress the pest.

The main domestically grown fruits (citrus, pome and stone) are produced over a total area of 344,198 hectares in Algeria, Libya, Morocco and Tunisia. Table I shows the total area of fruits in the Maghreb, by country. Citrus is the major crop overall (46% of total area), followed by stone fruits (30%) and pome fruits (24%). The table shows the

TABLE I. AVERAGE AREA, PRODUCTION AND YIELD OF CITRUS, POME AND STONE FRUITS IN MAGHREB COUNTRIES, 1980-1989

Area (thousand hectares)

	Algeria	Libya	Morocco	Tunisia	Maghreb
Citrus	37	35	71	14	157
Pome	21	8.2	13.1	39	81.3
Stone	31	5.9	19.6	49.4	105.9
Total	89	49.1	103.7	102.4	344.2

Production (thousand tonnes)

Citrus	300	857	1095	210	2250
Pome	66	8	204	49	327
Stone	88	17	135	53	293

Yield (tonnes/ha)

Citrus	8.1	24.5	15.4	14.9	14.3
Pome	3.2	1.0	15.5	1.3	4.0
Stone	2.8	2.9	6.9	1.1	2.8

TABLE II. AVERAGE ANNUAL CHANGES IN PRODUCTION OF CITRUS, POME AND STONE FRUITS IN MAGHREB COUNTRIES (% PER YEAR), 1980-1989 (BASED ON REGRESSION OF FAO PRODUCTION DATA)

	Algeria	Libya	Morocco	Tunisia	Maghreb
Citrus	-3.75	2.66	3.03	5.00	3.15
Pome	9.82	7.44	14.95	10.06	13.00
Stone	4.88	9.64	4.14	0.00	3.74

relative importance of citrus, pome and stone fruits in the Maghreb. It also shows that the citrus area is mainly located in Morocco, Algeria and Libya and that pome and stone fruits are extensively cropped in Tunisia, Algeria and Morocco respectively.

Over the period 1980-1989, fruit production throughout the Maghreb has been increasing, except for citrus in Algeria (Table II). These trends do not account for price, inflation, agricultural and trade policy regime changes. These increases in production can be related to the incentives generated by relatively high fruit prices and high tariffs for fruit imports in these countries. Such a progression indicates that losses are likely to increase under the current medfly control technology, along with increased production. It is also possible that medfly is preventing an even more rapid intensification of fruit production in the region, especially for stone fruits, which are seriously attacked by medfly.

Table III presents the total annual loss for each crop and country. Citrus is the major source of loss, most of which is in Morocco. Monetary values have been assessed using domestic prices and exchange rates which prevailed during the period 1980-1989 [1]. Total losses are approximately US $60 million, half of which occur in Morocco. Algeria and Tunisia have lower loss levels occurring mainly on stone fruits even though physical losses are higher for citrus. This is related to the higher stone fruit prices in those countries. However, these figures should be treated with some caution, as they do not account for inconsistency in data, exchange rate overvaluations, price distortions and domestic inflation.

Also, when observing commodity losses, stone fruits account for half of the total loss from medfly in the Maghreb with Libya and Morocco losing the most. This situation can be explained by the relatively low level of control on stone fruits, which are mainly grown in the low input sector, and also because the harvesting periods coincide with peak medfly activity. Lower figures are obtained for citrus, much of which is exported in Morocco and Tunisia, where extensive medfly control has already been undertaken on these crops using bait and cover sprays in the high input sector. Citrus in Algeria and Libya is oriented to domestic markets, and although they have almost the same crop areas, total losses are higher in Libya because of higher yields (24 tonnes/ha, against 8 tonnes/ha in Algeria).

The second component of medfly costs on the host fruits is related to expenditures for pesticide applications. Medfly in the Maghreb is mainly controlled on commercial fruit farms using either bait or cover sprays, often applied by air on larger farms. Bait sprays consist of a mixture of insecticide (generally malathion or chlorpyrifos) with a protein derived from yeast extract. The protein bait emits ammonia, which is a strong attractant to both male and female fruit flies. The protein itself attracts female flies since it is required for egg maturation. The insecticide mixed with the bait then kills the flies very efficiently. In some cases cover sprays are used instead of bait applications, control is achieved by giving a good overall coverage of insecticide on the crop and killing the flies on contact. In principle, cover sprays are less efficient than bait sprays, but they may need to be used when other insects or diseases (for which baits do not work) are also being targeted by the same spray or spray mix. However, in much of the Maghreb the medfly is the only serious pest of fruit that requires control with pesticides.

The progressive increase of repeated pesticide applications presents an environmental pollution problem and little research has been conducted so far in the Maghreb on its consequences. In Morocco, Algeria and Tunisia, damage caused by mites, scale insects, aphids and aleurods in citrus is increasing, requiring in turn, more pesticide applications. Biological control based on the use of entomophagous insects has been tried in Algeria and Tunisia, however, large-scale insecticidal applications are a major obstacle. The economic consequences of the elimination of natural enemies from stone fruit and citrus orchards in Israel, where a national campaign based on area-wide bait sprays has been in progress throughout the last 30 years, are only poorly documented and studied.

TABLE III. AVERAGE ANNUAL LOSSES ATTRIBUTED TO MEDFLY ON CITRUS, POME AND STONE FRUITS IN MAGHREB COUNTRIES, 1980-1989

Total (thousand tonnes)

	Algeria	Libya	Morocco	Tunisia	Maghreb
Citrus	10.22	4.81	77.20	9.24	101.47
Pome	2.19	2.43	30.03	7.25	41.90
Stone	4.65	10.36	41.58	14.74	71.33

Total (US$ million)

	Algeria	Libya	Morocco	Tunisia	Maghreb
Citrus	1.02	2.91	8.77	1.06	13.76
Pome	0.44	3.67	9.95	1.61	15.67
Stone	0.93	12.33	13.93	3.49	30.68
Total	2.39	18.91	32.65	6.16	60.11

TABLE IVA. AVERAGE ANNUAL COST OF MEDFLY CONTROL ON CITRUS, POME AND STONE FRUITS IN MAGHREB COUNTRIES, 1980-1989 (BASED ON SURVEY DATA)

Total (US$ million)

	Algeria	Libya	Morocco	Tunisia	Maghreb
Citrus	0.65	2.13	3.85	0.38	7.01
Pome	0.48	0.12	0.40	0.11	1.11
Stone	0.56	0.12	0.63	0.16	1.47
Total	1.69	2.37	4.88	0.65	9.59

TABLE IVB. PROJECTIONS FOR 1990-1999 OF AVERAGE ANNUAL COST OF MEDFLY DAMAGE AND CONTROL ON CITRUS, POME AND STONE FRUITS

	Algeria	Libya	Morocco	Tunisia	Maghreb
Citrus	1.62	6.93	14.27	8.52	24.66
Pome	1.01	4.63	18.23	2.34	26.24
Stone	1.70	14.32	20.63	4.26	40.22
Total	4.33	25.88	53.13	15.12	91.12

Despite excellent control using bait sprays, some export quality fruit may need additional post-harvest control to meet the requirements of some importers. This may consist of chilling for several days, heating for several minutes or fumigation with methyl bromide, depending on the fruit species and the intended market. All fruit for export must be cleaned and culled to ensure good presentation in the market, which adds further to the cost of control of medfly.

On large commercial farms the effectiveness of insecticidal control of medfly is very good, with 8-10 sprays per season. Virtually all fruit should be free of fruit fly damage if properly sprayed. However, small farms producing for the domestic market apply fewer sprays, if any at all, and do so less effectively. Most home-grown fruits are not sprayed.

Even with fruit that has had completely effective medfly control, some export markets have quarantine regulations that prevent acceptance of even clean fruit from countries in which medfly is present (Japan and southern USA).

Table IVA shows that citrus is the main crop on which medfly is controlled in all four countries. The high cost of control in Morocco can be attributed to the high

proportion of export-oriented producers in that country, who use a greater number of bait or cover spray applications. Higher pesticide prices and labour costs, along with aircraft application prices explain the high control cost obtained for Libya. The lower levels of control costs per hectare in Algeria and Tunisia confirm the inconsistencies obtained when comparing countries. The same Table IVB shows losses and costs due to medfly projected over the next decade if both losses and control costs increase at the current rate of fruit production. Medfly losses for the Maghreb would reach US $81 million if no further action is taken, and control costs could rise to US $10 million at constant prices. Overall losses plus costs for the Maghreb would rise to US $91 million. In Section 4, these figures are adjusted and presented for the assessment of the future benefits obtained under alternative medfly control technologies.

1.1.2. Environmental costs

A simple measure of the environmental costs of current medfly control efforts can be obtained by calculating the amount of pesticide put into the environment. No figures are available on pesticide volumes used for medfly control in the Maghreb, but an approximation can be based on the total expenditure for control. Calculations are based on the assumptions that about 25% of total cost is made up of pesticide (the remainder is labour and equipment), and that most of the pesticide used is malathion at approximately US $10/litre at a concentration of 57% active ingredient (ai). On this basis, Table V presents estimates of malathion used by commodity and country. Subsequent estimates were produced using the market model described in Section 3.1 which suggest a lower level of pesticide use in the Maghreb (94 tonnes ai), in Morocco (45.6 tonnes), Libya (13 tonnes) and in Algeria (19.5 tonnes). In Tunisia the level of malathion used has been adjusted upward 16.25 tonnes. While malathion has relatively low mammalian toxicity, it is toxic to fish and beneficial insects. Other environmental costs, such as effect on honey production, water pollution and human health could not be considered due to a lack of data.

1.1.3. Benefits forgone under current control technologies

The direct benefits identified in most project analyses do not include all the indirect effects generated in the medium and long runs. Market development, quality enhancement

TABLE V. ESTIMATED VOLUMES (TONNES AI) OF MALATHION USED ON CITRUS, POME AND STONE FRUITS IN MAGHREB COUNTRIES, 1980-1989

	Algeria	Libya	Morocco	Tunisia	Maghreb
Citrus	8.1	26.6	48.1	4.7	87.6
Pome	6.0	1.5	5.0	1.4	13.9
Stone	7.0	1.5	7.9	2.0	18.4
Total	21.1	29.6	61.0	8.1	119.9

and fruit consumption effects are major cases considered here. If data were available, these foregone benefits could have been added to the current costs under the prevailing medfly control technologies.

1.1.3.1. Fruit consumption

With rising population and income in the Maghreb, demand for fruit is increasing and prices will continue to increase as well, for both fresh and processed fruit. Under the current control technologies consumers are loosing all these extra benefits given that demand moves faster than fruit supply and prices increase rapidly from year to year. So consumption may decline, and low income groups might have even lower consumption levels if the trend were to continue. The examples of the market models shown in the appendices indicate estimates of fruit consumption in four countries.

Consumers would benefit from lower fresh fruit prices if more efficient medfly controls are adopted. They would also benefit from the availability of higher grades of fruit, with a large diversity of fruit types. Processed fruits could be more available than at present, with increased consumption. Such increases in consumption, while benefiting all consumers, are likely to improve the nutritional status of low income groups.

1.1.3.2. Potential markets

More efficient medfly controls would increase national supplies of fruits and enhance their quality. Given the current intensity of medfly attacks on susceptible fruits and the losses generated, the projected levels of fruit supplies in the Maghreb countries show a progressive reduction in meeting the need of each economy. Loss of current export foreign markets, and potential new export opportunities, are likely to form major issues for Maghrebin economies. Maintaining and improving supplies to local and traditional foreign markets and gaining access to new export markets are among the major direct benefits to be achieved by a medfly control project. Furthermore, a net fruit importer such as Libya could reduce stone and pome fruit imports. Algeria could again export its excess supply. Moreover, expansion in domestic fruit markets is an important effect resulting from medfly control.

With regard to this last issue, each Maghrebin economy has an annual population growth of 2 to 3% with higher rates observed in cities. This implies that demand for fruits is mainly driven by urban population growth. Furthermore, with rising incomes for some of the population there will be a greater demand for higher fruit quality at reasonable prices for consumers in domestic markets.

Concerning regional trade among the Maghreb countries, and with the availability of diversified and higher fruit grades, improvements can be made in the overall Maghreb economy. These flows would increase the affordability of fruits and consequently contribute to nutritional improvements among low income consumer groups in each country.

In parallel with these regional and domestic markets, processing can be developed further to supply different qualities of processed fruits. This would increase the demand for lower fruit grades which are not suitable for consumption as fresh fruit.

Higher export levels can be reached if the overall quality of fresh and processed fruits improves. Traditional importers in Europe might allow for export increases if the required quality is met competitively by Maghreb countries. Also, new export markets can be developed under similar conditions (USA, Canada, Eastern Europe, Japan ...). While Morocco and Tunisia, as net exporters, would benefit more from these potential markets, Libya and Algeria could reach this target in the longer run. Libya can actively reduce its import levels for pome and stone fruits besides promoting citrus exports. Algeria can enhance its levels of supplies and enter export markets.

These domestic and foreign markets form the basis for potential market improvements and generate new streams of benefits to each economy. Such benefits would only develop with long-term medfly control strategies.

1.1.3.3. Fruit quality

The improvement of fruit quality is an important consequence of a medfly control project. As such, improvements can be observed at each stage of production, marketing and export. Furthermore, with the development of new fruit growing opportunities, new varieties and fruit species can be introduced and grown in different areas in the Maghreb, whenever production costs and returns allow such activities.

Along with improving yields, medfly control will improve fruit quality and contribute to reduced production and marketing costs. This might increase returns to fruit growers and merchants. Consumers are also potential gainers since they would have access to greater choice of fruit quality and might have lower prices due to higher level of supply. Moreover, higher nutritional possibilities are offered to low income groups.

Export possibilities would be enhanced with improved fruit quality and marketing standards. Contract renegotiation with the European Community could be more likely to be achieved under new sets of fruit grades and qualities. New export markets are also important to be considered under these conditions. Better fruit quality would be reflected in higher producer prices.

These changes in fruit quality may induce new production, marketing, consumption and trade of both fresh and processed fruits. As such, the impact of seasonality can be reduced since longer storage, preservation and processing can make the commodities available all-year-round. Such a change is likely to occur with the elimination of the major source of fruit damage. Fruit storage and conservation, along with the development of new fruit varieties, would expand the supply of fresh fruits over the year. These changes are major sources of indirect benefits to different economic agents. They induce new export possibilities based on the availability of fruits in different importing markets throughout the year. Early and late season fruit varieties can be expanded and new fruits introduced. Late season fruits, especially, would be encouraged by eliminating the build-up of medfly during the season. Currently, many late maturing varieties of fruit cannot be grown economically in the Maghreb because of medfly attack.

1.2. PROSPECTS FOR IMPROVED MEDFLY CONTROL

Under the assumptions adopted and with data limitations underlined in previous reports [1-6], the costs obtained are likely to be biased estimates of the level of loss involved since other host fruit losses are not included. Variations among countries and

crops are also important features to be considered. They are related to variations in loss rate estimates for each of the host fruits in different countries. Besides that, comparisons among countries are likely to be biased since cost figures are not adjusted for agricultural, price, exchange rate and trade policies. However, the likely impact of such problems are considered and costs are adjusted for the reference period in order to have consistent benefit estimates for the current situation.

Consequently, under the technologies which have been prevailing since 1980, the costs obtained herein show that important economic losses are occurring in each country and for the Maghreb as a whole. Such costs are increasing each year and affect producers and consumers. Producers are affected because of higher production costs while consumers pay higher prices. The medfly also affects other related sectors. Fruit processing (juices, jams, preserves, etc.) have higher prices and higher production costs. Furthermore, as the quality and quantity of fruit is increasingly affected by medfly attack, there may be reductions in exports in some countries (Morocco and Tunisia). Domestically marketed host fruits at the current and projected costs with reductions in supplies and with important shifts in demand (population growth 2 to 3% per year) will have progressive price increases. Under the current agricultural and trade policies involving high import tariffs on fruits (Algeria, Morocco and Tunisia), domestic prices will increase greatly implying reduction in per capita consumption for citrus, pome and stone fruits. With overvalued currencies, such as in Libya, consumers pay higher prices (imports and subsidies) in order to ensure domestic fruit consumption.

During the 1980s, structural adjustment programmes have begun to affect prices of agricultural commodities, including fruit, in the various Maghreb countries. These might lead to reduction of trade distortions with other countries. Under those policies, fruit imports will become possible and cheaper while fruit exports will become more valuable for each country. Consequently, medfly host fruit producers in complying with the new policies have to reduce their production costs in order to stay competitive in selling their commodities.

Fruit producers under any agricultural price policies are inclined to reduce their production costs in order to ensure income either from exports or domestic markets. Given the costs related to medfly damage and control occurring under the current technologies, it has been necessary to identify all the possible technological changes which might enhance the social benefits related to fruit production. Evaluation of costs and benefits related to each alternative technology over a 15 year horizon has permitted an appropriate ranking of the available options relative to the current situation. The options compared [1] consisted of area-wide pest management with and without SIT, and eradication from the entire Maghreb using SIT. Each of these area-wide medfly control programmes offers more efficient control than is currently available, and would relieve individual growers of the need to manage pests, especially in citrus, where medfly is the only serious pest. This would allow growers more time to develop and market their crops. These area-wide control options are described in the following section.

2. MEDFLY CONTROL OPTIONS

Three options are considered for the management of medfly in the Maghreb, apart from the present use of insecticide sprays by private fruit growers. All are regional programmes aimed at extending the benefits of medfly control to all fruit producers. The

options include regional SIT eradication, suppression using SIT, and suppression using bait sprays. Smaller areas for suppression can also be considered if countries choose to concentrate efforts on specific zones.

2.1. REGIONAL SIT ERADICATION

The general plan for an SIT eradication for medfly has been presented by a group of IAEA technical experts [7]. The plan is based on the experience of successful eradication campaigns using SIT for medfly in Central America. It also draws on experience gained in a recent programme in the Maghreb which very effectively eradicated the New World Screwworm in Libya using the same technique [8], as had been done previously in the USA and Mexico. A great deal of experience in operating and evaluating medfly eradication has been assembled in the operational MOSCAMED programmes in Mexico and Guatemala [9]. MOSCAMED began in 1979 and operates under ecological conditions ranging from very arid to humid tropical. In addition, the economic status of farmers, fruit wholesalers, exporters and local consumers have many similarities to the Maghreb region.

The plan requires an initial preliminary phase of three years to collect data about medfly abundance in different areas and seasons and to make detailed plans on the timing and intensity of the subsequent eradication programme. During the third year of the preliminary phase a fruit fly rearing and irradiating facility (fly factory) would be built. It would also be possible to import flies from surplus capacity in Central America or Hawaii, but in the event of a major medfly emergency in the USA, these factories may not be able to continue supplying flies to the Maghreb.

The eradication programme would be conducted across the region in zones, nominally estimated by the technical experts at 5,000 km^2 each [7]. As eradication is achieved or approached in each zone, the campaign would be extended to the next zone. It is expected that the entire operation would take nine years (one zone per year), but there may be some opportunity to speed up the progress in later years as more experience is gained. The medfly population would be suppressed at the start of the season in the eradication zone using bait sprays, mainly applied by air. Once trapping showed that populations had been reduced to low levels, sterilized flies would be released by air during the first two years at a rate of 100,000 per km^2 per week if both sexes are used, or 50,000 if males only are used. During the second year of eradication in each zone, pockets of residual populations would be eliminated by intensive release of sterile flies or bait spraying.

During the eradication programme, intensive quarantine would be implemented to check or limit movement of fruit into the zone from neighbouring medfly-infested areas. In Algeria and Morocco this would require some internal quarantines for several years. After eradication has been achieved, a quarantine system should be maintained to prevent the accidental introduction of fruit flies from outside the region.

The size of the nine zones has been estimated in more detail in the present study, based on the known area of susceptible fruit production in the four countries, and an estimation of the extent of the potential wild medfly reservoirs in each country. The area of wild reservoirs is greater further to the west. In Morocco a ratio of 1:12 for cultivated and wild host areas is assumed. There are, for example, approximately 120,000 ha of fruit and about 700,000 ha of argan forest. Much of the land in fruit-growing areas is not

in susceptible fruit, but since flies are released by air and disperse, an area considerably in excess of the actual host area must also be included. The ratio of known host areas of 1:6 is therefore doubled. The ratio in Algeria is estimated to be 1:8, while in Tunisia and Libya, where hosts are more limited, it is assumed to be 1:4. From these ratios and the known areas of fruit, estimated sizes for the eradication zones are calculated as follows: Libya (2,500 km^2); Tunisia (5,250 km^2); Algeria (3 zones of 2,700 km^2); and Morocco (4 zones of 3,900 km^2). The total area to be treated is estimated to be much less than the 220,000 km^2 in which medfly could live based on bioclimatic indicators [9]. Much of that area is extensively cultivated with non-host crops such as wheat and barley, and some is marginal to medfly survival in colder winters.

It is assumed that the number of sterile flies which will be needed each year will, on average, be enough to treat one zone at the full rate for a first period, and one zone at a half rate during a second period (see action plan in Appendix 2). The maximum requirement for sterile flies would come in year two of implementation taking into account a reserve production capacity of about 1 billion a week.

2.2. REGIONAL SUPPRESSION USING SIT

A major cost in an eradication programme involves sampling and quarantine, plus application of eradication efforts to large areas of non-economic wild hosts. Costs can, therefore, be reduced by concentrating efforts on suppression of medfly only in the economic areas, and by not taking as rigorous an approach to sampling.

Suppression can be carried out without bait spraying at the beginning of the season. Flies would be released at the same rate as for eradication, but only for the duration of the commercial cropping season. Treatments would occur in all zones eventually, which would require three fly factories of the size needed for SIT eradication. The construction of factories would be phased over three years. Implementation could begin in approximately one-third of the area in the year after each factory was built. Much of the preliminary phase to collect data on medfly abundance would still be required. Fly releases would continue as a recurrent expense.

Pesticide application would be eliminated, and the benefits of medfly control extended to smaller commercial and home producers who make relatively lower effort to control medfly now. However, there would be no improvement in export markets without eradication.

The SIT has been effectively used in the pink bollworm management programme in California cotton each year for 23 years [11, 12]. Pheromone traps and SIT release over cotton-growing areas at a rate of 6 million moths per day are the main programme component. The total programme cost in 1991-92 was US $6.3 million to protect about US $780 million of annual output (gross sales value of cotton at world prices) spread over about 0.49 million ha in the San Joaquin Valley. Growers pay a levy based on their reported cotton production and this levy covers about 87% of the total programme cost. The strategy does not aim at eradication, but maintains low population levels so that farmers do not need to apply insecticides.

2.3. REGIONAL SUPPRESSION USING BAIT SPRAYS

It would also be possible to give smaller producers the benefits of medfly control, and reduce the levels of spraying currently practised by large citrus growers, by an area-wide aerial bait application programme. Regional control would reduce reinvasion on farms currently spraying against medfly. Some new technologies, such as improved monitoring and better baits and application equipment, could make a regional bait programme much more efficient than individual applications.

Bait sprays would be applied every 10 to 14 days throughout the fruit season. Bait applications would be made in all areas of fruit production, but not in wild reservoirs. A preliminary planning phase would be necessary, as with the other options, to establish good practices under local conditions. This option could be undertaken in all zones simultaneously. While it would broaden the benefits of medfly control in the same way as SIT suppression, it would increase the volume of pesticide used to control medfly in the Maghreb. The potential for secondary pest outbreaks is thereby increased [13] and there may ultimately be problems with insecticide resistance, although this has not yet occurred in medfly control programmes since 1956 [14].

One of the major innovations of the regional bait suppression option is the use of co-ordinated control over multi-farm areas of management. The increased effectiveness of area-wide management has been recognized for mobile pests by entomologists in many programmes [15, 16, 17]. However, it is usually very difficult to quantify these advantages per hectare or per dollar of product produced at various scales of operation and over time without actual trial experience. Costs of inputs are known, but scale economies and level of effectiveness vary greatly with the speed and intensity of reinvasion of pests, the costs of local quarantine, the costs of clean-up of reinvasions, the speed of the spread of the area-wide management campaign and product price changes [18, 19, 20].

For the Maghreb region the most similar experience of organized, area-wide management for medfly comes from Israel [14]. An area-wide bait programme is also planned for Mauritius [21]. The speed of adoption of area-wide bait application will be more rapid than voluntary IPM (integrated pest management) programmes, but there might be efficiencies relative to the base technology for the Maghreb region because of reduced fruit losses and less spread of infested fruit. While bait applications may be at high levels relative to current use in low-input orchards, total insecticide application may decline on some commercial orchards because of reduced infestation from surrounding wild areas.

3. COST-BENEFIT ANALYSIS

A standard 15 year time horizon is used to compare all the management options. This time-scale was chosen to cover the longest of the three options (eradication). It includes three phases in each option, the first three years are devoted to a pre-implementation research and planning phase, implementation would then be undertaken over one to nine years, and a further three years are included to show post implementation recurrent costs and benefits. A constant 8% discount rate is assumed, based on interest and inflation rates in the region during the 1980-1989 period.

Net present values for the discounted stream of costs and benefits, benefit/cost ratios and the internal rate of return to investment (IRR) are computed. Return on equity is assessed as the ratio of the present value of positive terms over negative terms in the cumulative flow of costs and benefits. The pay-back period is established to indicate how quickly benefits are generated through the project.

Environmental benefits for various management options are indicated by comparing the cost of pesticide-based medfly control before and after the implementation of the project. A standard time unit of ten years is used for this comparison. Thus, for all projects, pesticide expenditures for ten years at current rates and at post-implementation rates are compared. It is assumed throughout that the same pesticide is used in each stage and in each project (generally malathion), and that the proportion of pesticide material to application costs remains constant. Given these assumptions, the dollar value of pesticide-based control operations is a good index of the amount of pesticide entering the environment. Approximately one quarter of the cost of pesticide use is attributable to pesticide itself. Therefore, US $1 million spent on medfly control is equivalent to approximately 12,500 kg malathion ai (US $250,000 @ US $10/litre and 50% ai).

Estimates of fruit production, medfly losses and control costs for the four Maghreb countries were presented in the previous sections. This forms the foundation of the estimates of the potential benefits from improved medfly management. These estimates have been incorporated into a computer model of production, losses and control which provided standardized estimates for each country and the region. The model has two advantages over the raw data on losses and control collected in each of the four countries. Standard functions are used to make a loss and control cost estimate for each country, so the reasons for differences in production, costs and prices across countries are more clearly explained. More importantly, the implications of changes in the fruit production system as a result of medfly management are more easily predicted and illustrated.

3.1. MAGHREB FRUIT FLY AND MARKET MODEL

A spreadsheet model was developed to make estimates of market losses and costs under a range of possible medfly control options (the functions are described in Table VI, while example output is shown in Table VII). The programme estimates fruit production, values and control costs for three groups of commodities (citrus, pome and stone fruits), for two production sectors (high and low input commercial growers) and for three markets (exports requiring and not requiring fruit fly free quality, and the combined domestic market and home consumption). Inputs include crop areas and potential yields for each commodity and production sector, fruit prices and price elasticities, control costs and performance estimates, the extent of control, and the human population of the area.

Some of the inputs of the model are based on relatively reliable data (for example, crop areas and average yields). Other inputs are based on assumptions which should be tested further (average fruit fly damage and control functions). However, the model has value in two ways at present. It can be used to test outputs from realistic ranges of inputs (sensitivity analysis), and it serves as a framework for determining additional data needs.

Crop areas in each of the two producer sectors are based on reported crop areas in each of the four Maghreb countries. Potential yields were estimated from area and production data.

TABLE VI. FUNCTIONS USED IN THE FRUIT FLY AND MARKET MODEL (FUNCTIONS IN [] ARE CALCULATED VALUES, OTHERS ARE INPUT BY THE USER)

Potential production	■ crop area (hectares by commodity and sector) ■ potential yield (kg/ha by commodity and sector)
Damage	■ [potential production (by commodity and sector)] ■ uncontrolled % medfly damage (by commodity and sector)
Control	■ % reduction of damage when control is used (by sector) ■ average number of treatments by sector
Control cost	■ unit costs of control ■ average number of treatments by sector
From the inputs and functions above the production of each commodity by each sector is estimated, and losses and control costs are calculated for each commodity and sector.	
Prices	■ farm gate prices at local market quality ■ farm gate prices at export quality
Distribution	■ three markets (fly-free export, export, domestic) ■ export market limits (by commodity) ■ high input commercial production goes to export markets until export limits are reached, any excess goes into the domestic market at local prices ■ all low input domestic production goes into the domestic market
Market response	■ in the export market the prices are considered to be constant regardless of local production, which is assumed to be a small proportion of the total world market ■ the domestic market takes all production in excess of export limits, at constant crop prices
From these functions losses due to medfly can be attributed to markets and the overall net crop value can be determined.	
Consumption indices	■ [consumption (kg/yr) of domestic produce] ■ [per capita expenditure on fruit in domestic market at farm gate price] ■ [average domestic market farm gate price ($/kg) weighted by commodity]

The damage function assumes that uncontrolled medfly losses are greater in less intensive production (due, for instance, to less intense crop hygiene, or delayed harvesting). Uncontrolled loss estimates range from 20% in high input citrus to 60% in low input stone fruit.

The control functions assume that high input commercial growers get about 80% control, while low input commercial growers get about 20% control. Control in this case is expressed as the reduction in the potential damage for that crop and sector. Current control costs are assumed to average about US $40/ha for high input growers and US $10/ha for low input growers. This is equivalent to approximately 4 bait spray

TABLE VII. AN EXAMPLE RUN OF THE FRUIT FLY AND MARKET MODEL FOR THE MAGHREB

Maghreb Fruit Fly and Market Run: Maghreb total

PRODUCTION AND CONTROL VARIABLES

Ha ('000)	Total area	348	Production (kg/ha)		Potential production
	High input	Low input	High input	Low input	('000 tonnes)
citrus	92	66	16000	10000	2132
pome	8	75	6000	2500	235
stone	20	87	10000	2500	417

Damage functions (% loss)			Control (% loss saved)		Average loss (%)
	High input	Low input	High input	Low input	despite control
citrus	20	30	80	20	10
pome	30	45	80	20	29
stone	40	60	80	20	28

Sprays per season (average)			Spray cost (@$10/ha)		Total control cost
	High input	Low input	High input	Low input	($ million)
citrus	4	1	3.68	0.66	4.34
pome	5	1	0.40	0.75	1.15
stone	6	1	1.20	0.87	2.07

MARKET VARIABLES

	Price ($/kg)	Market limit ('000 T)	Quantity ('000 T)	Gross crop value ($ million) Market	Subtotal
Fly-free certified exports					
citrus	1.00	0.00	0.00	0.00	
pome	1.00	0.00	0.00	0.00	
stone	0.70	0.00	0.00	0.00	
					0.00
Exports not requiring fly-free certificate					
citrus	1.00	470.00	470.00	470.00	
pome	1.00	0.00	0.00	0.00	
stone	0.70	2.00	2.00	1.40	
					471.40
Domestic market					
citrus	0.15		1444.72	216.71	
pome	0.30		165.12	49.54	
stone	0.30		295.10	88.53	
					354.77
				Total	826.17

LOSS AND CONTROL COST SUMMARY

Loss by market ($m)			Loss by commodity (T'000)	($m)	Control ($m)	Loss plus cost ($m)
Exports (fly-free)						
citrus	0.00	citrus	217.28	32.59	4.34	36.93
pome	0.00	pome	69.88	21.11	1.15	22.26
stone	0.00	stone	119.90	36.12	2.07	38.19
	0.00					
Exports (not fly-free)						
citrus	0.00					
pome	0.00					
stone	0.00					
	0.00					
Domestic						
citrus	32.59					
pome	21.11					
stone	36.12					

Population (m)	63.00
Consumption (kg/yr)	30.24
Mkt expenditure ($/yr)	5.63
Avg mkt price ($/kg)	0.19

Crop loss ($m)	89.826
Control cost ($m)	7.560
Net crop value ($m)	818.614

applications per year in high input and 1 per year in low input sectors. While many producers treat more frequently, some may not treat as much. The figures for low input growers are quite nominal, since many may have widely scattered trees.

On these assumptions the model calculates an expected production for each crop in each sector and distributes it into the various markets. A limit on export sales is set based on recent exports from each country. There is evidence that some export quality fruit goes onto the domestic market because the export market is satisfied. Up to the limit for the export markets, produce from high input commercial producers goes to export at export prices. The rest of the production goes to the domestic market, which varies in price from country to country.

TABLE VIII. CURRENT ANNUAL LOSSES AND CONTROL COSTS DUE TO MEDFLY IN THE MAGHREB COUNTRIES BASED ON THE FRUIT FLY AND MARKET MODEL OUTPUT (US$ MILLION)

Losses

	Algeria	Libya	Morocco	Tunisia	Maghreb
Citrus	7.39	17.35	5.89	2.81	32.59
Pome	4.25	1.18	7.70	8.42	21.11
Stone	5.69	0.66	18.72	10.63	36.12
Total	17.33	19.19	32.31	21.86	89.83

Control costs

Citrus	0.66	0.66	2.66	0.36	4.34
Pome	0.29	0.16	0.31	0.39	1.15
Stone	0.61	0.21	0.70	0.55	2.07
Total	1.56	1.03	3.67	1.30	7.56

Total losses and control costs

Citrus	8.05	18.01	8.55	3.17	36.93
Pome	4.54	1.34	8.01	8.81	22.26
Stone	6.30	0.87	19.42	11.18	38.19
Total	18.89	20.22	35.98	23.16	97.39

Losses are determined by comparing production of each crop in each market with the potential production assuming there is no damage. Therefore, loss equals potential production minus the production calculated under the given set of damage, control and adoption functions. Losses are calculated in tonnes.

The value of production (and also losses) is calculated assuming constant prices (although market value for organic produce may be higher). Export prices are assumed to be constant, since Maghreb production is only a part of a larger international market, while domestic prices could be greatly affected by changes in the amount of produce sold locally. The areas under cultivation are also assumed to be constant. It would be difficult to predict the additional benefits related to expansion of production areas without some values for production costs other than pest control.

Benefits from other control strategies can be estimated by replacing the control effect and cost functions in the benefit model (Table VIII).

For instance, in an eradication programme all growers would have control and all would get 100% control (compared with the partial control shown in the current situation in Table VIII). The control function for each crop and sector would then be 100% and if the private control cost is set at US$0.00 then a gross revenue can be determined.

Runs of the model with estimates of the current situation in each of the four countries are shown in Appendix 2.

3.2. MODEL OUTPUT

The model described above has been used to produce revised standard tables for medfly losses and control costs (Table IX) for the four Maghreb countries under current conditions.

These figures are revisions of those based on the 1990 survey [2-6]. In most cases the revision accounts for some consistent underestimation of losses. There are very significant deviations from the survey estimates for stone fruit losses in Libya, in which the loss given in the survey came to an unlikely US $2,000/ha/yr. Losses on citrus, however, were considerably increased in the model, probably accounting for underestimation of the large low input commercial sector in the country. Overall losses

TABLE IX. ANNUAL BENEFITS BY ZONES, BASED ON FRUIT FLY AND MARKET MODEL (US$ MILLION) WITHOUT INCREASES IN EXPORT MARKETS

	Crop loss	Pesticide costs	Total
Libya	19.190	1.030	20.220
Tunisia	21.860	1.300	23.160
Algeria (3 zones)	5.770	0.520	6.290
Morocco (4 zones)	8.700	0.910	9.610

estimated by the model are about 50% greater than those obtained from the national surveys, which may understate losses in the low input sectors.

Table IX shows that most of the medfly control in the Maghreb is associated with citrus, especially in Morocco where there is a large high input commercial sector. Control costs estimated from the model are about 40% higher than those reported in the survey (see Table IV), in keeping with the higher estimates of losses.

3.2.1. Costs and benefits for control zones

Because of the plan to introduce SIT eradication in nine annual zones all benefits and costs for each option must be calculated on the basis of these zones so that the options can be compared accurately. Libya and Tunisia are treated as individual zones, Algeria is divided into three equal zones, and Morocco into four equal zones. All benefits and costs in Algeria and Morocco are divided equally among their zones. Both benefits and costs vary for the zones in the four countries because of different total areas of the zones, and different distributions of fruit crops and production sectors.

3.2.2. Assumptions about performance

All three options (eradication and suppression) are assumed to eliminate losses from medfly, either completely or to negligible amounts on cultivated fruits. Eradication has the added advantage of potentially opening markets that are closed to producers in medfly-infested countries. As a result, benefits are assumed to include prevention of all current losses and control costs. These losses and costs (equivalent to the benefits shown in Table IX) were calculated using the market model illustrated for each country in Appendix 2.

3.2.3. Action schedule and costs

The actions undertaken in each year of the three options are shown in tables in Appendix 2, along with unit costs per area. A sterilized fly rearing facility suitable for producing enough flies to release in up to three zones at a time is expected to be around US $20 million to construct, based on experience with such factories in Central America.

Total operating costs for each zone for each option are shown in Table X. More detailed costs for the SIT eradication option by zones are shown in tables in Appendix 2.

A breakdown of costs associated with SIT eradication is shown in Figure 1.

3.2.4. Projection of costs and benefits over time

The cost-benefit analysis for each option is based on a projection of the actions and associated benefits and costs over a 15 year time period for each case. The actions (for each zone in each year) for the various options were entered into a matrix in a spreadsheet model which produced outputs illustrated in Section 4. The model consists of three main parts: a table showing the status of activity in each zone over each year; a table of benefits and costs by year for the project; and a table of benefit indices derived from calculations over the entire period. All projects are entered into the tables in the same way, but with different costs and benefits associated with their respective action plans.

TABLE X. ANNUAL COSTS BY ZONES, BASED ON FRUIT FLY AND MARKET MODEL (US$ MILLION) FOR THREE MEDFLY MANAGEMENT OPTIONS

Annual costs by zones

(US$ million)

SIT Eradication	Year	Eradication phase		Post
	0	1	2	3>>>>
All eradication costs				
Libya		15.035	10.097	1.704
Tunisia		31.573	21.204	3.579
Algeria (3 zones)		13.151	8.326	1.311
Morocco (4 zones)		17.282	10.593	1.599
SIT fly factory(ies)	20.000			
Bait application costs				
Libya		2.080	1.040	0.000
Tunisia		4.368	2.184	0.000
Algeria (3 zones)		1.296	0.648	0.000
Morocco (4 zones)		1.344	0.672	0.000

SIT Suppression	Year	Suppression every year		
	0	1	2	3>>>>
All control costs				
Libya		4.000	4.000	4.000
Tunisia		8.401	8.401	8.401
Algeria (3 zones)		3.802	3.802	3.802
Morocco (4 zones)		5.204	5.204	5.204
SIT fly factory(ies)	20.000	20.000	20 000	
Bait application costs				
Libya		0.520	0.520	0.520
Tunisia		1.092	1.092	1.092
Algeria (3 zones)		0.324	0.324	0.324
Morocco (4 zones)		0.336	0.336	0.336

BAIT Suppression	Year	Bait applied every year		
	0	1	2	3>>>>
All control costs				
Libya		6.762	6.762	6.762
Tunisia		14.200	14.200	14.200
Algeria (3 zones)		4.267	4.267	4.267
Morocco (4 zones)		4.478	4.478	4.478
SIT fly factory(ies)	0.000			
Bait application costs				
Libya		5.200	5.200	5.200
Tunisia		10.920	10.920	10.920
Algeria (3 zones)		3.240	3.240	3.240
Morocco (4 zones)		3.360	3.360	3.360

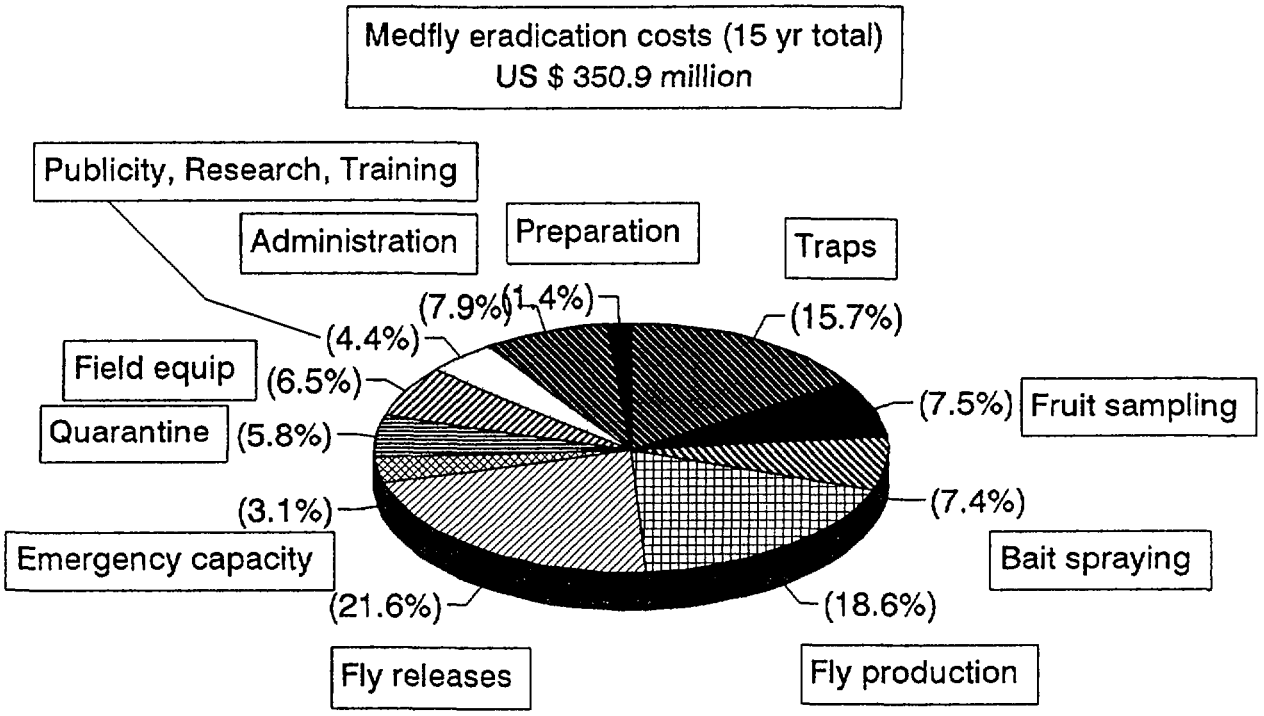

Figure 1. Breakdown of SIT eradication costs.

3.3. RISKS

It must be noted that the benefit and cost models used in this study do not take into account risks associated with breakdown or delay of new technologies or of quarantine breaches by new species. While the emergency capacity associated with the SIT options includes some bait spray capability, if a fruit fly species other than medfly became established then the regional bait suppression would be the only option that would maintain low losses and high benefits without much greater costs.

There is some flexibility to deal with changing conditions and objectives within the various programmes considered. If SIT eradication efforts were unsuccessful, or activities delayed, then SIT suppression could be undertaken as an alternative. Similarly, if SIT suppression was started, and eradication appeared within reach, the SIT suppression project could be expanded or extended to achieve the new goal.

Other potential risks are related to changes which can occur to fruit production from general environmental conditions, or from changing market demand. These factors could either increase or decrease the benefits of eradication or suppression of the medfly. However, such risks are independent of medfly control and foreseeable changes should not affect the viability of any of the options.

Risks from changes to any of the inputs in the fruit fly and market model could be tested, but such a procedure would be very time-consuming and has not been applied at this stage.

TABLE XI. COST-BENEFIT ANALYSIS FOR SIT ERADICATION OVER NINE ANNUAL ZONES FROM MOROCCO TO LIBYA

Cost-Benefit Analysis for MAGHREBMED

(values in US$ million)

Analysis Morocco to Libya SIT eradication

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Project phase	Phase 2			Phase 3									Project complete			
Status by zone (annual)																Costs (cum)
Morocco				ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	33 274
Morocco					ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	31 675
Morocco						ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	30 076
Morocco							ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	28 477
Algeria								ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	21 017
Algeria									ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	19 706
Algeria										ERAD	ERAD	ERAD	ERAD	ERAD	ERAD	18 395
Tunisia											ERAD	ERAD	ERAD	ERAD	ERAD	42 310
Libya												ERAD	ERAD	ERAD	ERAD	18 443
Benefits (annual)																
Total	0 000	0 000	0 000	8 996	17 991	26 987	35 982	42 278	48 574	54 870	78 034	98 259	98 259	98 259	98 259	706 747
Costs (annual)																
SIT - eradication				17 282	27 875	27 875	27 875	23 745	21 477	21 477	39 899	36 239	2 000	0 000	0 000	253 840
Factory			20 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	20 000
Post-eradication maintenance				0 000	0 000	1 599	3 199	4 798	6 397	7 708	9 019	10 330	19 429	19 429	19 429	88 185
Phase 2 preparation	1 500	2 000	1 500													5 000
Total	1 500	2 000	21 500	17 282	27 875	29 474	31 074	28 542	27 874	29 185	48 918	46 569	24 006	15 613	15 613	367 025
Net benefits (annual)	-1 500	-2 000	-21 500	-8 286	-9 884	-2 488	4 908	13 736	20 700	25 685	29 116	51 690	74 253	82 646	82 646	339 722
Net benefits (cumulative)	-1 500	-3 500	-25 000	-33 286	-43 170	-45 658	-40 749	27 014	-6 314	19 371	48 487	100 177	174 430	257 076	339 722	339 722

Benefit indices

Overall	
Net present value (US$ m)	112 49
Benefit/cost ratio (B/C)	1 59
Return on equity (N/K)	*4 26*
Internal rate of return (IRR) (%)	28 22
Pay-back period (years)	10

Present value of gross benefits by country (US$ m)	
Libya	28 730
Tunisia	42 839
Algeria	53 381
Morocco	177 509
Total	302 459

Comparison of pesticide use projected over 10 years (US$ m)		
	Current	Post-eradication
Libya	10 300	0 000
Tunisia	13 000	0 000
Algeria	15 600	*0 000*
Morocco	36 700	0 000
Total	75 600	0 000

Notes

A 15 year time period is used to compare all projects This is based on a time frame for SIT eradication involving 3 years pre-implementation, 9 years SIT campaigns by zones and 3 years post-implementation Pesticide use includes application costs It is compared over 10 years to account for the length of the transition period to eradication

Discount rate 0 08

The discount rate of 8% is based on interest and inflation rates in the region during 1980-1990

TABLE XII. COST-BENEFIT ANALYSIS FOR SIT SUPPRESSION OVER FOUR ANNUAL STEPS FROM MOROCCO TO LIBYA

Cost-Benefit Analysis for MAGHREBMED

(values in US$ million)

Analysis: Morocco to Libya SIT suppression

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Project phase	Phase 2			Phase 3									Project complete			
Status by zone (annual)																Costs (cum)
Morocco				SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	57.249
Morocco				SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	57.249
Morocco					SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	52.045
Morocco					SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	52.045
Algeria							SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	30.419
Algeria							SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	30.419
Algeria							SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	30.419
Tunisia						SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	75.606
Libya							SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	SIT-SUPP	32.002
Benefits (annual)																
Total	0.000	0.000	0.000	17.991	35.982	59.146	98.259	98.259	98.259	98.259	98.259	98.259	98.259	98.259	98.259	997.450
Costs (annual)																
SIT - suppression				10.409	20.818	18.810	23.808	15.407	0.000	0.000	0.000	0.000	0.000	0.000	0.000	89.252
Factory			20.000	20.000	20.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	60.000
Suppression maintenance				0.000	0.000	10.409	20.818	29.219	44.626	44.626	44.626	44.626	44.626	44.626	44.626	372.827
Phase 2 preparation	1.500	2.000	1.500													5.000
Total	1.500	2.000	21.500	30.409	40.818	29.219	44.626	44.626	44.626	44.626	44.626	44.626	44.626	44.626	44.626	527.078
Net benefits (annual)	-1.500	-2.000	-21.500	-12.418	-4.836	29.927	53.633	53.633	53.633	53.633	53.633	53.633	53.633	53.633	53.633	470.372
Net benefits (cumulative)	-1.500	-3.500	-25.000	-37.418	-42.254	-12.326	41.307	94.940	148.573	202.206	255.839	309.472	363.105	416.739	470.372	470.372

Benefit indices

Overall		Present value of gross benefits by country (US$ m)		Comparison of pesticide use projected over 10 years (US$ m)		
					Current	Post-suppression
Net present value (US$ m)	197.40	Libya	79.618	Libya	10.300	5.200
Benefit/cost ratio (B/C)	1.75	Tunisia	105.785	Tunisia	13.000	10.920
Return on equity (N/K)	7.06	Algeria	74.354	Algeria	15.600	9.720
Internal rate of return (IRR) (%)	51.16	Morocco	202.034	Morocco	36.700	13.440
Pay-back period (years)	7	Total	461.791	Total	75.600	39.280

Notes: A 15 year time period is used to compare all projects. This is based on a time frame for SIT eradication involving 3 years pre-implementation, 9 years SIT campaigns by zones, and 3 years post-implementation. Pesticide use includes application costs. It is compared over 10 years to account for the length of the transition period to eradication.

Discount rate 0.08

The discount rate of 8% is based on interest and inflation rates in the region during 1980-1990.

TABLE XIII. COST-BENEFIT ANALYSIS FOR BAIT SPRAY SUPPRESSION

Cost-Benefit Analysis for MAGHREBMED

(values in US$ million)

Analysis: Simultaneous BAIT suppression

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Project phase	Phase 2			Phase 3									Project complete			
Status by zone (annual)																Costs (cum)
Libya				BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	74 380
Tunisia				BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	156 197
Algeria				BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	46 941
Algeria				BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	46 941
Algeria				BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	46 941
Morocco				BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	49 255
Morocco				BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	49 255
Morocco				BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	49 255
Morocco				BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	BAIT	49 255
Benefits (annual)																
Total	0 000	0 000	0 000	98 259	98 259	98 259	98 259	98 259	98 259	98 259	98 259	98 259	98 259	98 259	98 259	1179 108
Costs (annual)																
Factories			0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000
BAIT suppression				51 674	51 674	51 674	51 674	51 674	51 674	51 674	51 674	51 674	51 674	51 674	51 674	620 093
Phase 2 preparation	0 300	0 300	0 400													1 000
Total	0 300	0 300	0 400	51 674	51 674	51 674	51 674	51 674	51 674	51 674	51 674	51 674	51 674	51 674	51 674	621 093
Net benefits (annual)	-0 300	-0 300	-0 400	46 585	46 585	46 585	46 585	46 585	46 585	46 585	46 585	46 585	46 585	46 585	46 585	558 015
Net benefits (cumulative)	-0 300	-0 600	-1 000	45 585	92 169	138 754	185 338	231 923	278 507	325 092	371 677	418 261	464 846	511 430	558 015	558 015

Benefit indices

Overall		Present value of gross benefits by country (US$ m)		Comparison of pesticide use projected over 10 years (US$ m)		
					Current	Post-suppression
Net present value (US$ m)	277 83	Libya	120 994	Libya	10 300	52 000
Benefit/cost ratio (B/C)	1 90	Tunisia	138 576	Tunisia	13 000	109 200
Return on equity (N/K)	326 90	Algeria	112 995	Algeria	15 600	97 200
Internal rate of return (IRR) (%)	436 97	Morocco	215 258	Morocco	36 700	134 400
Pay-back period (years)	4	Total	587 823	Total	75 600	392 800

Notes

A 15 year time period is used to compare all projects This is based on a time frame for SIT eradication involving 3 years pre-implementation, 9 years SIT campaigns by zones, and 3 years post-implementation Pesticide use includes application costs It is compared over 10 years to account for the length of the transition period to eradication

Discount rate 0 08

The discount rate of 8% is based on interest and inflation rates in the region during 1980-1990

4. RESULTS OF COST-BENEFIT ANALYSES

The results of cost-benefit analyses for five scenarios are presented in this section. Each output is presented in a similar format for easy comparison. The action plan is presented in the upper part of each table, a summary of benefits by year in the central part, and a table of benefit indices is presented in the lower part.

4.1. REGIONAL SIT ERADICATION

The IAEA technical experts proposed an eradication campaign based on nine annual zones [7]. A modification of this plan is illustrated in Table XI. There is some possibility for accelerating this plan in the latter part of the project, as experience is gained. However, the more conservative nine year plan was used for comparison.

4.2. REGIONAL SUPPRESSION USING SIT

The SIT suppression option is assumed to be accomplished more rapidly than eradication (Table XII). It includes the construction of three fly factories in successive years, with four steps of implementation. After the initial preparatory phase, suppression would begin in two zones of Morocco in the first year, expand to the rest of Morocco in the second year, all of Tunisia in the third year and Algeria and Libya in the fourth year. Overall, the benefits of this intermediate option are very favourable, although it involves very high capital costs for factories and does not present a final solution to the medfly problem (with opportunities for some increases in export markets), as eradication does.

4.3. REGIONAL SUPPRESSION USING BAIT SPRAYS

The bait suppression option could be implemented more rapidly than the other options and requires no major capital inputs (Table XIII). However, it is the most expensive option overall, and would greatly increase the amount of pesticide in the environment. Like SIT suppression, it does not give a final solution to the medfly problem, nor does it give any potential to open new markets that do not accept fruit from medfly-infested areas.

5. DISCUSSION

Various criteria can be considered to compare the three area-wide medfly control programmes (Table XIV). Net present value, benefit/cost ratio, the internal rate of return and the pay-back period show that all three options are better than current control. Bait suppression gives the best overall financial return over the first 15 year period. However, once established, SIT eradication becomes the dominant strategy in terms of annual net benefits (Figure 2). Alternative estimates for bait suppression using lower and higher rates of annual pesticide sprays are shown in Table XV. At around 13 bait applications per fruit season, the bait spray option becomes less economic than SIT suppression over the initial 15 year period.

Using an environmental indicator, the value of pesticide use (Table XIV), shows clearly that the area-wide bait suppression gives an inferior outcome to the two SIT schemes.

TABLE XIV. ECONOMIC AND ENVIRONMENTAL INDICATORS FOR THREE MEDFLY CONTROL OPTIONS COMPARED TO CURRENT CONTROL, OVER A 15 YEAR PERIOD

	Options			
	Now (current control)	Area-wide Bait Suppression	Area-wide SIT Suppression	Area-wide SIT Eradication
Economic Indicators				
Net present value (15 yr @ 8%) (US$ million)	-	278	197	112
Benefit/cost ratio	-	1.90	1.75	1.59
Internal rate of return (%)	-	437	51	28
Annual net return after implementation (US$ million)	-	47	54	83
Pay-back period (years after Phase 2)	-	1	4	7
Environmental Indicators				
Net change in pesticide use per year (US$ million)	-	+31.8	-3.6	-7.5
Pesticide use per year (US$ million)	7.5	39.3	3.9	0

Note: Pesticide use costs include both cost of materials and application, but represent similar proportions of active ingredient. Pesticide use in SIT suppression may be limited to "clean-up" and barrier treatments around the edge of orchards, and may not contribute to residues on the fruit. Some bait applications would be used in the initial phase of SIT eradication, but no pesticide would be needed after the first two years in each eradication zone (except in the event of occasional local quarantine operations).

The economic advantages of area-wide bait suppression are offset by higher environmental costs and the potential loss of export market shares if current markets in North America and Europe become more discriminating against perceived pesticide residues and medfly presence in producing countries (see Figure 3 and Table XVII).

Both SIT-based control schemes have been costed assuming dedicated fly factories are built specifically for the project. However, an alternative budget could be based on purchasing flies from commercially operated fly factories, reducing capital investment, but paying higher rates for the flies when needed. In Table XVI these two alternatives are compared, using a commercial rate of US $300 per million flies (male plus female) compared to US $175/million from dedicated factories. At these prices there is little change in the net present value over 15 years, but much higher internal rates of return,

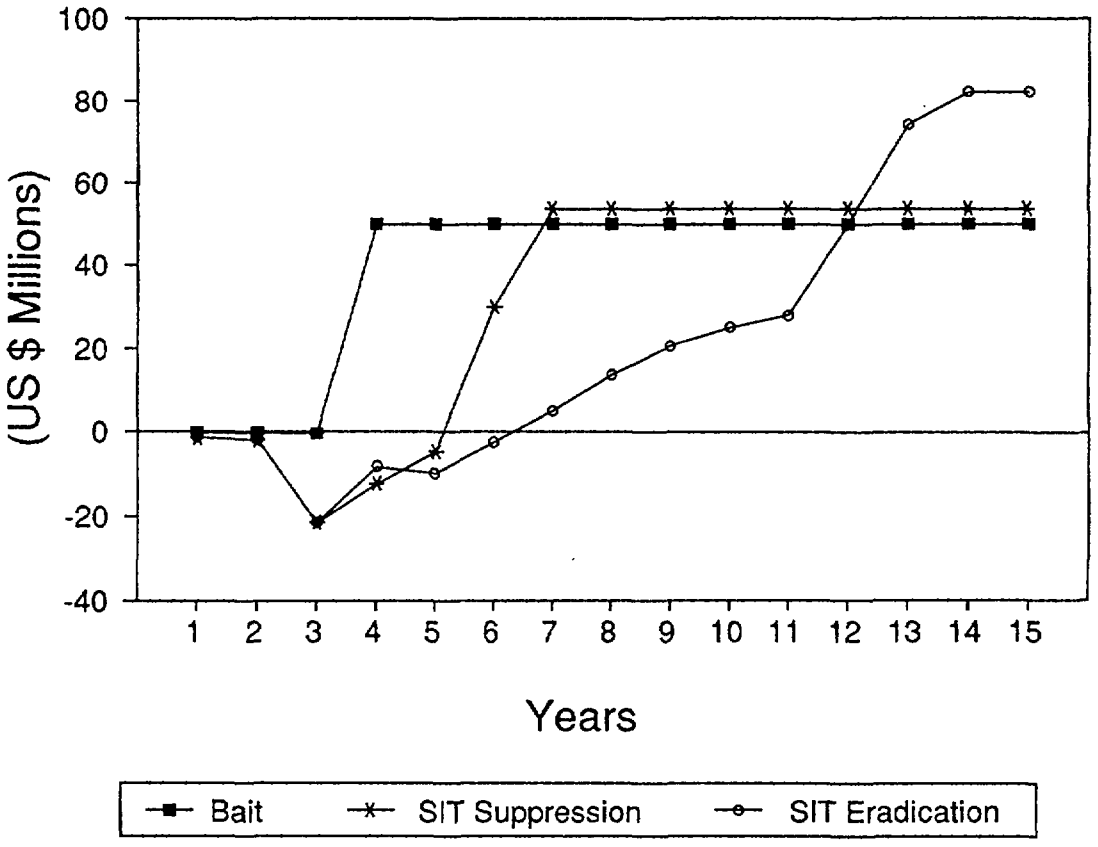

Figure 2. Annual net benefits of SIT eradication.

due to lower capital outlay. An attraction of commercial fly production is that there would be inducements to keep costs low and to look for additional markets which could spread overhead costs. However, a commercial producer may need a long initial contract for fly sales to give him the confidence to risk his capital.

Other indirect benefits are those to be gained from expanding fruit export markets. Under the current medfly control technologies, fruit cannot be sold outside markets which do not discriminate on the basis of very low pesticide residues or fly-free status in the field. New markets could be gained under the new alternatives. If fruit exports must be "pesticide-free" or "fly-free" to enter a market, then area-wide SIT programmes give better potential access to these markets (Table XVII and Figure 3).

Falling fruit prices and production costs following medfly eradication may put pressure on less efficient producers, resulting in changes in the fruit production and processing industries. While some fruit producers and processors may leave the industries, others may be encouraged to enter or expand once the constraint of medfly control has been eliminated.

These analyses are based on a programme covering all of the Maghreb. It is possible that suppression programmes, using either bait or SIT, could be undertaken on a smaller scale, either as a preliminary phase of the overall programme or as separate initiatives. Eradication is less feasible on a smaller scale due to the problem of reinvasion. The costs of small-scale suppression programmes can be calculated on an area basis, as in the case of the overall programmes discussed above. However, the benefits depend on the type of

TABLE XV. ECONOMIC AND ENVIRONMENTAL INDICATORS FOR THREE LEVELS OF BAIT APPLICATION IN AREA-WIDE BAIT SUPPRESSION OVER A 15 YEAR PERIOD (THE 10x/yr OPTION IS USED FOR COMPARISON WITH OTHER CONTROL OPTIONS)

	Options			
	Now (current control)	Area-wide Bait Suppression 7x/yr	Area-wide Bait Suppression 10x/yr	Area-wide Bait Suppression 13x/yr
Economic Indicators				
Net present value (15 yr @ 8%)	-	365	278	191
Benefit/cost ratio	-	2.63	1.90	1.48
Internal rate of return (%)	-	488	437	374
Annual net return after implementation (US$ million)	-	61	47	32
Pay-back period (years after Phase 2)	-	1	1	1
Environmental Indicators				
Net change in pesticide use per year (US$ million)	-	+20.0	+31.7	+43.0
Pesticide use per year (US$ million)	7.5	27.5	39.3	50.5

TABLE XVI. COMPARISON OF SOME ECONOMIC INDICATORS FOR SIT-BASED CONTROL OPTIONS WITH INTERNALLY COSTED FLY FACTORIES AND FLIES PRODUCED AT COST VS EXTERNALLY-FUNDED FLY FACTORIES WITH FLIES PURCHASED AT MARKET PRICES

	SIT Suppression		SIT Eradication	
	Internal factory	Purchased flies	Internal factory	Purchased flies
Factory cost (US$ million)	3 @ 20 60 total	-	1 @ 20 20 total	-
Fly price per million (males plus females) (US$)	175	300	175	300
Net present value over 15 years @ 8%	197	199	112	108
Internal rate of return (%)	51	109	28	32

TABLE XVII. THE OPTIMAL MEDFLY CONTROL STRATEGY IS VERY SENSITIVE TO RELATIVELY SMALL CHANGES IN THE DEMANDS OF THE EXPORT MARKET

Optimum strategy on economic criteria	Potential changes from current, relatively non-discriminating export markets		
	Non-discriminating	"Pesticide-free" or very low MRLs	"Fly-free" certified
Area-wide bait suppression	-	Less than 3.5% of market share going to discriminating markets	
Area-wide SIT suppression	-	More than 3.5% of market share	Less than 3.5% of market share
Area-wide SIT eradication	-	-	More than 3.5% of market share

Note: The current Maghreb export fruit market is about 470,000 tonnes, all to a relatively non-discriminating market (in terms of very low MRLs* or pest-free status in the field; the quality of the fruit itself must be very high to enter these markets). A 3.5% share of the market would represent about 16,500 tonnes. No price premium is expected for either of the potential discriminating markets.

The value of 3.5% change is based on the net present value over 15 years at 8% discount for a change in the market after year 3 (when controls would start to be implemented). In Table XIV the net present value of bait is US$81 million more than SIT suppression, which in turn is US$85 million more than SIT eradication. These are both equivalent to approximately 16,500 tonnes of fruit going into either of the more discriminating export markets.

Both the European and North American markets are likely to demand lower MRL or "pesticide-free" produce in the future. This would require changes in the current medfly control practices to maintain the current Maghreb share of those markets. A shift of over 3.5% in these markets is quite feasible, but could also evaporate if public interest in "pesticide-free" fruit waned.

The southern US and Japanese markets would demand "fly-free" certification of the production area before entry could be considered (however, entry could then be prevented for other reasons). The markets would be lost for several years if any quarantine breaches occurred.

*MRL is Maximum Residue Level permitted for pesticides on produce.

fruit grown in the area and its current level of management. The most likely areas to undertake small-scale suppression are ones in which there is a high concentration of high-input fruit production. Such areas are likely to benefit mainly from reduced pesticide residues rather than improved control. With SIT suppression, producers in such an area could enter a pesticide free market. Small-scale SIT operations would depend on a reliable commercial supply of sterile flies in the Mediterranean region.

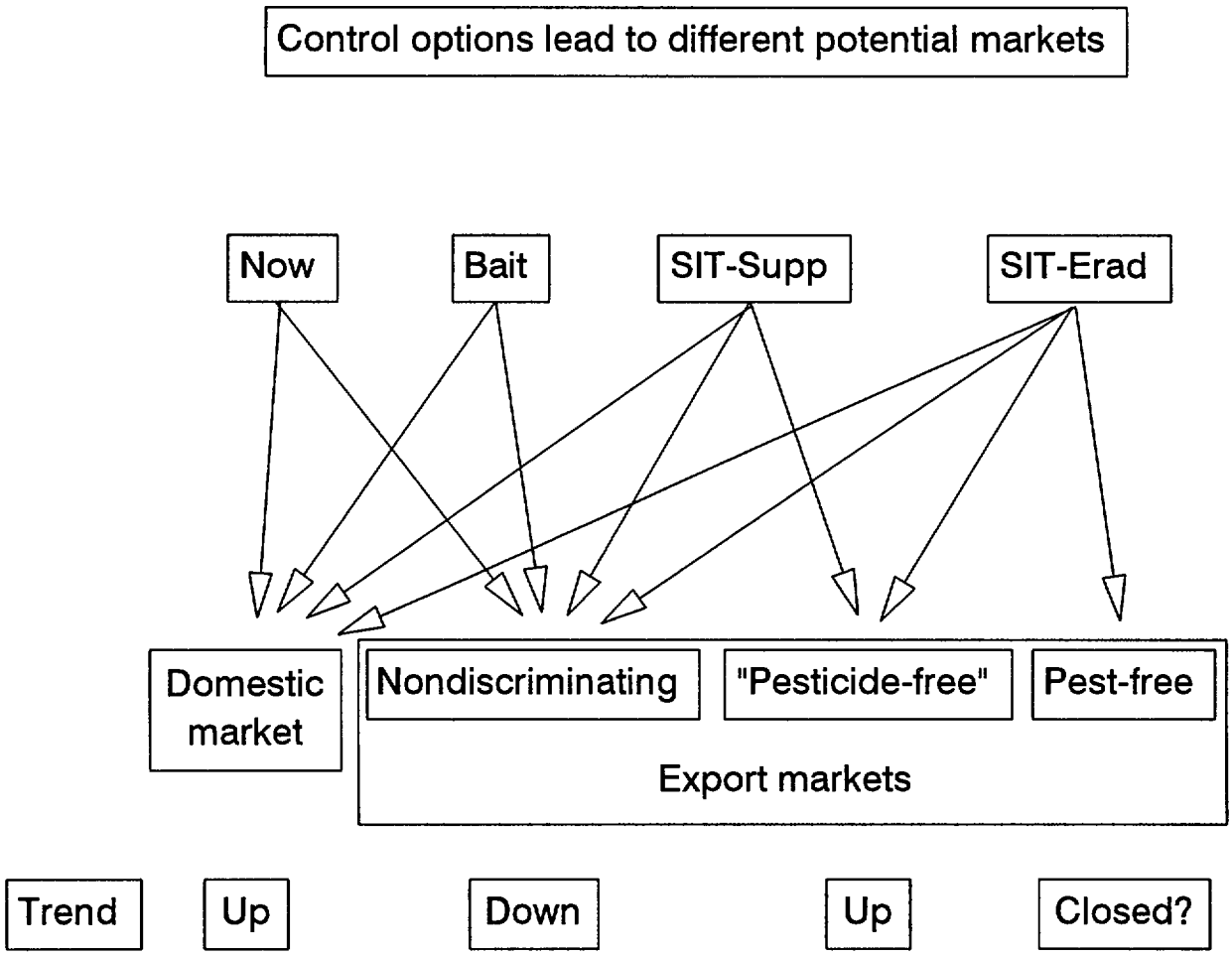

Figure 3. In addition to the economic indicators presented for static markets, medfly control strategies should be considered in relation to changing future markets. Both domestic and export markets for Maghreb fruit are relatively non-discriminating now, but trends suggest that the high value export market will become more concerned with pesticide residues. Note that area-wide bait suppression could also possibly achieve pest-free conditions, but considerable additional quarantine and sampling effort would be needed for fly-free certification, the costs of which have not been considered in the budgets used in this report for bait suppression.

6. CONCLUSION

On a combination of economic and environmental grounds, both SIT suppression and eradication are desirable management options for medfly in the Maghreb. SIT suppression would give access to "pesticide-free" or low MRL (maximum residue level) markets which are expected to increase in the future. It does not require extensive additional quarantine measures and is relatively risk-free. A SIT eradication programme operated successively in nine phased zones (of 2,500 to 5,250 km^2) starting in Morocco (or Libya) and moving one zone each year until the medfly is eradicated in Libya (or Morocco), would be a technically appealing option. It would provide a long-term solution to the medfly problem with relatively low inputs once established and open the possibility of access to further "fly-free" markets. However, the need for sustained quarantine efforts are very important, and there is the risk that much of the benefit gained from early success could be lost if medfly was allowed to re-enter the region. The strengthened

quarantine infrastructure, preventing the entry of other exotic fruit fly pests, would be an additional benefit for the Maghreb countries.

About 40% of the costs are related to sterile fly production and release while 30% to trapping, sampling and quarantine activities. The remaining 30% covers field equipment, administration, research, emergencies and other activities.

All the benefit indices described for the SIT suppression and eradication of the medfly in the Maghreb are favourable, both in economic and environmental terms. The techniques have been proven in large-scale programmes on the American Continent. With adequate funding provided for quarantine and emergency capacity, the risk of successful reinvasion by medfly, or invasion by a new fruit fly species, is minimized, and benefits should continue well beyond the end of the project.

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Appendix 1

LIST OF EXPERTS

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Appendix 2

ADDITIONAL TABLES AND CALCULATIONS

Table 1

Maghreb Fruit Fly and Market Run: Algeria

PRODUCTION AND CONTROL VARIABLES					
Ha ('000) Total area		88	Production (kg/ha)		Potential production
	High input	Low input	High input	Low input	('000 tonnes)
citrus	10	26	12000	10000	380
pome	2	19	4000	2000	46
stone	6	25	2000	1500	49
Damage functions (% loss)			Control (% loss saved)		Average loss (%)
	High input	Low input	High input	Low input	despite control
citrus	20	30	80	20	17
pome	30	45	80	20	30
stone	40	60	80	20	38
Sprays per season (average)			Spray cost (@$10/ha)		Total control cost
	High input	Low input	High input	Low input	($ million)
citrus	4	1	0.40	0.26	0.66
pome	5	1	0.10	0.19	0.29
stone	6	1	0.36	0.25	0.61

MARKET VARIABLES					
	Price ($/kg)	Market limit ('000 T)	Quantity ('000 T)	Gross crop value ($ million) Market	Subtotal
Fly-free certified exports					
citrus	1.00	0.00	0.00	0.00	
pome	1.00	0.00	0.00	0.00	
stone	0.70	0.00	0.00	0.00	
					0.00
Exports not requiring fly-free certificate					
citrus	1.00	0.00	0.00	0.00	
pome	1.00	0.00	0.00	0.00	
stone	0.70	0.00	0.00	0.00	
					0.00
Domestic market					
citrus	0.11		312.80	34.41	
pome	0.30		31.84	9.55	
stone	0.30		30.54	9.16	
					53.12
				Total	53.12

LOSS AND CONTROL COST SUMMARY						
Loss by market ($m)			Loss by commodity (T'000)	($m)	Control ($m)	Loss plus cost ($m)
Exports (fly-free)						
citrus	0.00	citrus	67.20	7.39	0.66	8.05
pome	0.00	pome	14.16	4.25	0.29	4.54
stone	0.00	stone	18.46	5.69	0.61	6.30
	0.00					
Exports (not fly-free)						
citrus	0.00					
pome	0.00					
stone	0.00					
	0.00					
Domestic						
citrus	7.39					
pome	4.25					
stone	5.69					

Population (m)	25.00
Consumption (kg/yr)	15.01
Mkt expenditure ($/yr)	2.12
Avg mkt price ($/kg)	0.14

Crop loss ($m)	17.328
Control cost ($m)	1.560
Net crop value ($m)	51.562

Table 2

Maghreb Fruit Fly and Market Run: Libya

PRODUCTION AND CONTROL VARIABLES					
Ha ('000)	Total area	50	Production (kg/ha)		Potential production
	High input	Low input	High input	Low input	('000 tonnes)
citrus	10	26	12000	8500	341
pome	2	6	4000	1600	17
stone	3	3	2000	1200	9
Damage functions (% loss)			Control (% loss saved)		Average loss (%)
	High input	Low input	High input	Low input	despite control
citrus	20	30	80	20	16
pome	30	45	80	20	23
stone	40	60	80	20	24
Sprays per season (average)			Spray cost (@$10/ha)		Total control cost
	High input	Low input	High input	Low input	($ million)
citrus	4	1	0.40	0.26	0.66
pome	5	1	0.10	0.06	0.16
stone	6	1	0.18	0.03	0.21

MARKET VARIABLES					
	Price	Market limit	Quantity	Gross crop value ($ million)	
	($/kg)	('000 T)	('000 T)	Market	Subtotal
Fly-free certified exports					
citrus	1.00	0.00	0.00	0.00	
pome	1.00	0.00	0.00	0.00	
stone	0.70	0.00	0.00	0.00	
					0.00
Exports not requiring fly-free certificate					
citrus	1.00	0.00	0.00	0.00	
pome	1.00	0.00	0.00	0.00	
stone	0.70	0.00	0.00	0.00	
					0.00
Domestic market					
citrus	0.30		283.16	84.95	
pome	0.30		13.66	4.10	
stone	0.30		7.39	2.22	
					91.26
				Total	91.26

LOSS AND CONTROL COST SUMMARY						
Loss by market ($m)			Loss by commodity		Control	Loss plus
			(T'000)	($m)	($m)	cost ($m)
Exports (fly-free)						
citrus	0.00	citrus	57.84	17.35	0.66	18.01
pome	0.00	pome	3.34	1.18	0.16	1.34
stone	0.00	stone	1.61	0.66	0.21	0.87
	0.00					
Exports (not fly-free)						
citrus	0.00					
pome	0.00					
stone	0.00					
	0.00					
Domestic						
citrus	17.35					
pome	1.18					
stone	0.66					

Population (m)	4.08
Consumption (kg/yr)	74.56
Mkt expenditure ($/yr)	22.37
Avg mkt price ($/kg)	0.30

Crop loss ($m)	19.195
Control cost ($m)	1.030
Net crop value ($m)	90.235

Table 3

Maghreb Fruit Fly and Market Run: Morocco

PRODUCTION AND CONTROL VARIABLES						
Ha ('000)	Total area	106	Production (kg/ha)		Potential production	
	High input	Low input	High input	Low input	('000 tonnes)	
citrus	65	6	16000	12000		1112
pome	4	11	8000	6000		98
stone	10	10	18000	10000		280
Damage functions (% loss)			Control (% loss saved)		Average loss (%)	
	High input	Low input	High input	Low input	despite control	
citrus	20	30	80	20		5
pome	30	45	80	20		26
stone	40	60	80	20		22
Sprays per season (average)			Spray cost (@$10/ha)		Total control cost	
	High input	Low input	High input	Low input	($ million)	
citrus	4	1	2.60	0.06		2.66
pome	5	1	0.20	0.11		0.31
stone	6	1	0.60	0.10		0.7

MARKET VARIABLES					
	Price ($/kg)	Market limit ('000 T)	Quantity ('000 T)	Gross crop value ($ million) Market	Subtotal
Fly-free certified exports					
citrus	1.00	0.00	0.00	0.00	
pome	1.00	0.00	0.00	0.00	
stone	0.70	0.00	0.00	0.00	
					0.00
Exports not requiring fly-free certificate					
citrus	1.00	420.00	420.00	420.00	
pome	1.00	0.00	0.00	0.00	
stone	0.70	2.00	2.00	1.40	
					421.40
Domestic market					
citrus	0.10		633.12	63.31	
pome	0.30		72.32	21.70	
stone	0.30		215.60	64.68	
					149.69
				Total	571.09

LOSS AND CONTROL COST SUMMARY						
Loss by market ($m)			Loss by commodity ('000)	($m)	Control ($m)	Loss plus cost ($m)
Exports (fly-free)						
citrus	0.00	citrus	58.88	5.89	2.66	8.55
pome	0.00	pome	25.68	7.70	0.31	8.01
stone	0.00	stone	62.40	18.72	0.70	19.42
	0.00					
Exports (not fly-free)						
citrus	0.00					
pome	0.00					
stone	0.00					
	0.00					
Domestic						
citrus	5.89					
pome	7.70					
stone	18.72					

Population (m)	25.60
Consumption (kg/yr)	35.98
Mkt expenditure ($/yr)	5.85
Avg mkt price ($/kg)	0.16

Crop loss ($m)	32.312
Control cost ($m)	3.670
Net crop value ($m)	567.418

Table 4

Maghreb Fruit Fly and Market Run: Tunisia

PRODUCTION AND CONTROL VARIABLES					
Ha ('000)	Total area	104	Production (kg/ha)		Potential production
	High input	Low input	High input	Low input	('000 tonnes)
citrus	7	8	18000	12000	222
pome	0	39	4000	2000	78
stone	1	49	2000	1500	75
Damage functions (% loss)			Control (% loss saved)		Average loss (%)
	High input	Low input	High input	Low input	despite control
citrus	20	30	80	20	12
pome	30	45	80	20	36
stone	40	60	80	20	47
Sprays per season (average)			Spray cost (@$10/ha)		Total control cost
	High input	Low input	High input	Low input	($ million)
citrus	4	1	0.28	0.08	0.36
pome	5	1	0.00	0.39	0.39
stone	6	1	0.06	0.49	0.55

MARKET VARIABLES					
	Price	Market limit	Quantity	Gross crop value ($ million)	
	($/kg)	('000 T)	('000 T)	Market	Subtotal
Fly-free certified exports					
citrus	1.00	0.00	0.00	0.00	
pome	1.00	0.00	0.00	0.00	
stone	0.70	0.00	0.00	0.00	
					0.00
Exports not requiring fly-free certificate					
citrus	1.00	50.00	50.00	50.00	
pome	1.00	0.00	0.00	0.00	
stone	0.70	0.00	0.00	0.00	
					50.00
Domestic market					
citrus	0.10		143.92	14.39	
pome	0.30		49.92	14.98	
stone	0.30		40.06	12.02	
					41.39
				Total	91.39

LOSS AND CONTROL COST SUMMARY						
Loss by market ($m)			Loss by commodity		Control	Loss plus
			(T'000)	($m)	($m)	cost ($m)
Exports (fly-free)						
citrus	0.00	citrus	28.08	2.81	0.36	3.17
pome	0.00	pome	28.08	8.42	0.39	8.81
stone	0.00	stone	34.94	10.63	0.55	11.18
	0.00					
Exports (not fly-free)						
citrus	0.00					
pome	0.00					
stone	0.00					
	0.00					
Domestic						
citrus	2.81					
pome	8.42					
stone	10.63					

Population (m)	7.90
Consumption (kg/yr)	29.61
Mkt expenditure ($/yr)	5.24
Avg mkt price ($/kg)	0.18

Crop loss ($m)	21.864
Control cost ($m)	1.300
Net crop value ($m)	90.086

Table 5

Estimates of costs for medfly control programmes

Unit costs	$ per unit
Flies per million (males+females)	175.00
Release per million flies	300.00
Trap servicing (per trap)	3.17
Fruit sampling per sample	2.50
Lab ID per fly	0.02
Fruit sample analysis (per kg)	1.40
Bait spray per ha aerial in orchards	10.00
Bait spray in wild area	0.10
Quarantine (basic cost)	0.50
Emergency capacity (per total ha)	1.00
	% of variable costs
Capital field equipment	8.00
Publicity, research and training	5.00
Administration	10.00

Table 6

Action plan for medfly eradication

SIT Eradication Standard zone 1		Year 1	2	3	4	5	.....	15 yr Total (US$ m)
Area of orchards (ha)	100000	Eradication Phase		Fly-free post eradication period >>>>				
Multiple for non crop	4							
Total area (ha)	500000							

Traps/ha*	Units				
Orchards	0.1	0.2	0.02	0.02	0.02
Wild	0.005	0.01	0.002	0.002	0.002
Samples per year	52	52	52	52	52
Lab ID for traps (estimated flies/ha caught)**					
Orchards	10	10	5	5	5
Wild	1	1	0.5	0.5	0.5
Fruit sampling/ha					
Orchards	0.5	0.25	0	0	0
Wild	0.01	0.0002	0	0	0
Samples per year	26	26	0	0	0
Fruit sample analysis (kg/ha)					
Orchards	0.125	0.01	0	0	0
Wild	0.003	0.0002	0	0	0
Samples per year	26	26	0	0	0
Quarantine (intensity x basic cost)					
Orchards	0.15	0.4	0.4	0.4	0.4
Wild	0.01	0.004	0.004	0.004	0.004
Operations per year	52	52	52	52	52
Bait spray					
Operations per year	4	2	0	0	0
SIT release (million flies/ha)***					
Orchards	0.0005	0.0005	0	0	0
Wild vegetation	0.0005	0.0005	0	0	0
Operations per year	104	52	0	0	0

* It may be possible to reduce the level of trapping depending on the progress of eradication.
** This is an average figure based on anticipated sampling methods.
*** Equivalent to release of 100,000 flies/sq km/week in the first period (twice a week at 50,000 flies/sq km).

Table 7

Estimates of phased costs for medfly eradication programme

SIT Eradication Algeria zone 3		Year 1	2	3	4	5	.....	15 yr Total (US$ m)
Area of orchards (ha)	30000	Eradication Phase		Fly-free post eradication period >>>>				
Multiple for non crop	8							
Total area (ha)	270000							

Costs per zone

Total costs (US$ millions)						
Traps	1.254	1.946	0.459	0.459	0.459	9.165
Fruit sampling	1.131	0.491	0.000	0.000	0.000	1.622
Fruit sample analysis	0.163	0.013	0.000	0.000	0.000	0.175
Bait spraying	1.296	0.648	0.000	0.000	0.000	1.944
Fly production	2.457	1.229	0.000	0.000	0.000	3.686
SIT release of flies	4.212	2.106	0.000	0.000	0.000	6.318
Emergency capacity	0.000	0.000	0.270	0.270	0.270	3.510
Quarantine	0.179	0.337	0.337	0.337	0.337	4.897
Capital field equip	0.855	0.542	0.085	0.085	0.085	2.505
Publicity, research and training	0.535	0.338	0.053	0.053	0.053	1.566
Administration	1.069	0.677	0.107	0.107	0.107	3.132
Total	13.151	8.326	1.311	1.311	1.311	38.519

Total cost for country

Total costs (US$ millions)						
Traps	3.762	5.839	1.376	1.376	1.376	27.495
Fruit sampling	3.393	1.472	0.000	0.000	0.000	4.865
Fruit sample analysis	0.488	0.038	0.000	0.000	0.000	0.526
Bait spraying	3.888	1.944	0.000	0.000	0.000	5.832
Fly production	7.371	3.686	0.000	0.000	0.000	11.057
SIT release of flies	12.636	6.318	0.000	0.000	0.000	18.954
Emergency capacity	0.000	0.000	0.810	0.810	0.810	10.530
Quarantine	0.538	1.011	1.011	1.011	1.011	14.691
Capital field equip	2.566	1.625	0.256	0.256	0.256	7.516
Publicity, research and training	1.604	1.015	0.160	0.160	0.160	4.697
Administration	3.208	2.031	0.320	0.320	0.320	9.395
Total	39.454	24.978	3.933	3.933	3.933	115.557

Table 8

Estimates of phased costs for medfly eradication programme

SIT Eradication Libya zone	1	Year 1	2	3	4	5	.....	15 yr Total (US$ m)
Area of orchards (ha)	50000	Eradication Phase		Fly-free post eradication period >>>>				
Multiple for non crop	4							
Total area (ha)	250000							

Costs per zone

Total costs (US$ millions)						
Traps	1.717	2.706	0.595	0.595	0.595	12.155
Fruit sampling	1.755	0.815	0.000	0.000	0.000	2.570
Fruit sample analysis	0.249	0.020	0.000	0.000	0.000	0.269
Bait spraying	2.080	1.040	0.000	0.000	0.000	3.120
Fly production	2.275	1.138	0.000	0.000	0.000	3.413
SIT release of flies	3.900	1.950	0.000	0.000	0.000	5.850
Emergency capacity	0.000	0.000	0.250	0.250	0.250	3.250
Quarantine	0.247	0.541	0.541	0.541	0.541	7.818
Capital field equip	0.978	0.657	0.111	0.111	0.111	3.076
Publicity, research and training	0.611	0.410	0.069	0.069	0.069	1.922
Administration	1.222	0.821	0.139	0.139	0.139	3.845
Total	15.035	10.097	1.704	1.704	1.704	47.287

Total cost for country

Total costs (US$ millions)						
Traps	1.717	2.706	0.595	0.595	0.595	12.155
Fruit sampling	1.755	0.815	0.000	0.000	0.000	2.570
Fruit sample analysis	0.249	0.020	0.000	0.000	0.000	0.269
Bait spraying	2.080	1.040	0.000	0.000	0.000	3.120
Fly production	2.275	1.138	0.000	0.000	0.000	3.413
SIT release of flies	3.900	1.950	0.000	0.000	0.000	5.850
Emergency capacity	0.000	0.000	0.250	0.250	0.250	3.250
Quarantine	0.247	0.541	0.541	0.541	0.541	7.818
Capital field equip	0.978	0.657	0.111	0.111	0.111	3.076
Publicity, research and training	0.611	0.410	0.069	0.069	0.069	1.922
Administration	1.222	0.821	0.139	0.139	0.139	3.845
Total	15.035	10.097	1.704	1.704	1.704	47.287

Table 9

Estimates of phased costs for medfly eradication programme

SIT Eradication Morocco zone	4	Year 1	2	3	4	5	.....	15 yr Total (US$ m)
Area of orchards (ha)	30000	Eradication Phase		Fly-free post eradication period >>>>				
Multiple for non crop	12							
Total area (ha)	390000							

Costs per zone

Total costs (US$ millions)						
Traps	1.478	2.269	0.561	0.561	0.561	11.037
Fruit sampling	1.209	0.492	0.000	0.000	0.000	1.701
Fruit sample analysis	0.176	0.014	0.000	0.000	0.000	0.189
Bait spraying	1.344	0.672	0.000	0.000	0.000	2.016
Fly production	3.549	1.775	0.000	0.000	0.000	5.324
SIT release of flies	6.084	3.042	0.000	0.000	0.000	9.126
Emergency capacity	0.000	0.000	0.390	0.390	0.390	5.070
Quarantine	0.211	0.349	0.349	0.349	0.349	5.103
Capital field equip	1.124	0.689	0.104	0.104	0.104	3.165
Publicity, research and training	0.703	0.431	0.065	0.065	0.065	1.978
Administration	1.405	0.861	0.130	0.130	0.130	3.957
Total	17.282	10.593	1.599	1.599	1.599	48.666

Total cost for country

Total costs (US$ millions)						
Traps	5.911	9.075	2.243	2.243	2.243	44.147
Fruit sampling	4.836	1.969	0.000	0.000	0.000	6.805
Fruit sample analysis	0.703	0.054	0.000	0.000	0.000	0.757
Bait spraying	5.376	2.688	0.000	0.000	0.000	8.064
Fly production	14.196	7.098	0.000	0.000	0.000	21.294
SIT release of flies	24.336	12.168	0.000	0.000	0.000	36.504
Emergency capacity	0.000	0.000	1.560	1.560	1.560	20.280
Quarantine	0.842	1.398	1.398	1.398	1.398	20.411
Capital field equip	4.496	2.756	0.416	0.416	0.416	12.661
Publicity, research and training	2.810	1.723	0.260	0.260	0.260	7.913
Administration	5.620	3.445	0.520	0.520	0.520	15.826
Total	69.126	42.374	6.397	6.397	6.397	194.662

Table 10

Estimates of phased costs for medfly eradication programme

SIT Eradication Tunisia zone	1	Year 1	2	3	4	5	.....	15 yr Total (US$ m)
Area of orchards (ha)	105000	Eradication Phase		Fly-free post eradication period >>>>				
Multiple for non crop	4							
Total area (ha)	525000							

Costs per zone

Total costs (US$ millions)						
Traps	3.606	5.683	1.249	1.249	1.249	25.526
Fruit sampling	3.686	1.712	0.000	0.000	0.000	5.397
Fruit sample analysis	0.524	0.041	0.000	0.000	0.000	0.565
Bait spraying	4.368	2.184	0.000	0.000	0.000	6.552
Fly production	4.778	2.389	0.000	0.000	0.000	7.166
SIT release of flies	8.190	4.095	0.000	0.000	0.000	12.285
Emergency capacity	0.000	0.000	0.525	0.525	0.525	6.825
Quarantine	0.519	1.136	1.136	1.136	1.136	16.418
Capital field equip	2.054	1.379	0.233	0.233	0.233	6.459
Publicity, research and training	1.283	0.862	0.145	0.145	0.145	4.037
Administration	2.567	1.724	0.291	0.291	0.291	8.073
Total	31.573	21.204	3.579	3.579	3.579	99.303

Total cost for country

Total costs (US$ millions)						
Traps	3.606	5.683	1.249	1.249	1.249	25.526
Fruit sampling	3.686	1.712	0.000	0.000	0.000	5.397
Fruit sample analysis	0.524	0.041	0.000	0.000	0.000	0.565
Bait spraying	4.368	2.184	0.000	0.000	0.000	6.552
Fly production	4.778	2.389	0.000	0.000	0.000	7.166
SIT release of flies	8.190	4.095	0.000	0.000	0.000	12.285
Emergency capacity	0.000	0.000	0.525	0.525	0.525	6.825
Quarantine	0.519	1.136	1.136	1.136	1.136	16.418
Capital field equip	2.054	1.379	0.233	0.233	0.233	6.459
Publicity, research and training	1.283	0.862	0.145	0.145	0.145	4.037
Administration	2.567	1.724	0.291	0.291	0.291	8.073
Total	31.573	21.204	3.579	3.579	3.579	99.303

Table 11

Action plan for medfly control

SIT Suppression Standard zone 1		Year 1	2	3	4	5	.....	15 yr Total (US$ m)
Area of orchards (ha)	100000	SIT Suppression		SIT suppression continues >>>>				
Multiple for non crop	4							
Total area (ha)	500000							

Traps/ha*	Units				
Orchards	0.02	0.02	0.02	0.02	0.02
Wild	0.002	0.002	0.002	0.002	0.002
Samples per year	52	52	52	52	52
Lab ID for traps (estimated flies/ha caught)**					
Orchards	5	5	5	5	5
Wild	0.5	0.5	0.5	0.5	0.5
Fruit sampling/ha					
Orchards	0	0	0	0	0
Wild	0	0	0	0	0
Samples per year	0	0	0	0	0
Fruit sample analysis (kg/ha)					
Orchards	0	0	0	0	0
Wild	0	0	0	0	0
Samples per year	0	0	0	0	0
Quarantine (intensity x basic cost)					
Orchards	0	0	0	0	0
Wild	0	0	0	0	0
Operations per year	0	0	0	0	0
Bait spray					
Operations per year	1	1	1	1	1
SIT release (million flies/ha)***					
Orchards	0.0005	0.0005	0.0005	0.0005	0.0005
Wild	0.0005	0.0005	0.0005	0.0005	0.0005
Operations per year	36	36	36	36	36

* It may be possible to reduce the level of trapping depending on the progress of eradication.
** This is an average figure based on anticipated sampling methods.
*** Equivalent to release of 50,000/sq km/week in the first year.

Table 12

Estimates of phased costs for medfly control programmes

SIT Suppression Algeria zone 3		Year 1	2	3	4	5	.....	15 yr Total (US$ m)
Area of orchards (ha)	30000	SIT suppression		SIT suppression continues >>>>				
Multiple for non crop	8							
Total area (ha)	270000							

Costs per zone

Total costs (US$ millions)						
Traps	0.459	0.459	0.459	0.459	0.459	6.882
Fruit sampling	0.000	0.000	0.000	0.000	0.000	0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000	0.000
Bait spraying	0.324	0.324	0.324	0.324	0.324	4.860
Fly production	0.851	0.851	0.851	0.851	0.851	12.758
SIT release of flies	1.458	1.458	1.458	1.458	1.458	21.870
Emergency capacity	0.000	0.000	0.000	0.000	0.000	0.000
Quarantine	0.000	0.000	0.000	0.000	0.000	0.000
Capital field equip	0.247	0.247	0.247	0.247	0.247	3.710
Publicity, research and training	0.155	0.155	0.155	0.155	0.155	2.318
Administration	0.309	0.309	0.309	0.309	0.309	4.637
Total	3.802	3.802	3.802	3.802	3.802	57.035

Total cost for country

Total costs (US$ millions)						
Traps	1.376	1.376	1.376	1.376	1.376	20.647
Fruit sampling	0.000	0.000	0.000	0.000	0.000	0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000	0.000
Bait spraying	0.972	0.972	0.972	0.972	0.972	14.580
Fly production	2.552	2.552	2.552	2.552	2.552	38.273
SIT release of flies	4.374	4.374	4.374	4.374	4.374	65.610
Emergency capacity	0.000	0.000	0.000	0.000	0.000	0.000
Quarantine	0.000	0.000	0.000	0.000	0.000	0.000
Capital field equip	0.742	0.742	0.742	0.742	0.742	11.129
Publicity, research and training	0.464	0.464	0.464	0.464	0.464	6.955
Administration	0.927	0.927	0.927	0.927	0.927	13.911
Total	11.407	11.407	11.407	11.407	11.407	171.105

Table 13

Estimates of phased costs for medfly control programmes

SIT Suppression Libya zone	1	Year 1	2	3	4	5	.....	15 yr Total (US$ m)
Area of orchards (ha)	50000	SIT suppression		SIT suppression continues >>>>				
Multiple for non crop	4							
Total area (ha)	250000							

Costs per zone

Total costs (US$ millions)						
Traps	0.595	0.595	0.595	0.595	0.595	8.922
Fruit sampling	0.000	0.000	0.000	0.000	0.000	0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000	0.000
Bait spraying	0.520	0.520	0.520	0.520	0.520	7.800
Fly production	0.788	0.788	0.788	0.788	0.788	11.813
SIT release of flies	1.350	1.350	1.350	1.350	1.350	20.250
Emergency capacity	0.000	0.000	0.000	0.000	0.000	0.000
Quarantine	0.000	0.000	0.000	0.000	0.000	0.000
Capital field equip	0.260	0.260	0.260	0.260	0.260	3.903
Publicity, research and training	0.163	0.163	0.163	0.163	0.163	2.439
Administration	0.325	0.325	0.325	0.325	0.325	4.878
Total	4.000	4.000	4.000	4.000	4.000	60.004

Total cost for country

Total costs (US$ millions)						
Traps	0.595	0.595	0.595	0.595	0.595	8.922
Fruit sampling	0.000	0.000	0.000	0.000	0.000	0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000	0.000
Bait spraying	0.520	0.520	0.520	0.520	0.520	7.800
Fly production	0.788	0.788	0.788	0.788	0.788	11.813
SIT release of flies	1.350	1.350	1.350	1.350	1.350	20.250
Emergency capacity	0.000	0.000	0.000	0.000	0.000	0.000
Quarantine	0.000	0.000	0.000	0.000	0.000	0.000
Capital field equip	0.260	0.260	0.260	0.260	0.260	3.903
Publicity, research and training	0.163	0.163	0.163	0.163	0.163	2.439
Administration	0.325	0.325	0.325	0.325	0.325	4.878
Total	4.000	4.000	4.000	4.000	4.000	60.004

Table 14

Estimates of phased costs for medfly control programmes

SIT Suppression Morocco zone 4		Year 1	2	3	4	5	.....	15 yr Total (US$ m)
Area of orchards (ha)	30000	SIT suppression		SIT suppression continues >>>>				
Multiple for non crop	12							
Total area (ha)	390000							

Costs per zone

Total costs (US$ millions)							
Traps	0.561	0.561	0.561	0.561	0.561		8.412
Fruit sampling	0.000	0.000	0.000	0.000	0.000		0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000		0.000
Bait spraying	0.336	0.336	0.336	0.336	0.336		5.040
Fly production	1.229	1.229	1.229	1.229	1.229		18.428
SIT release of flies	2.106	2.106	2.106	2.106	2.106		31.590
Emergency capacity	0.000	0.000	0.000	0.000	0.000		0.000
Quarantine	0.000	0.000	0.000	0.000	0.000		0.000
Capital field equip	0.339	0.339	0.339	0.339	0.339		5.078
Publicity, research and training	0.212	0.212	0.212	0.212	0.212		3.173
Administration	0.423	0.423	0.423	0.423	0.423		6.347
Total	5.204	5.204	5.204	5.204	5.204		78.067

Total cost for country

Total costs (US$ millions)							
Traps	2.243	2.243	2.243	2.243	2.243		33.647
Fruit sampling	0.000	0.000	0.000	0.000	0.000		0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000		0.000
Bait spraying	1.344	1.344	1.344	1.344	1.344		20.160
Fly production	4.914	4.914	4.914	4.914	4.914		73.710
SIT release of flies	8.424	8.424	8.424	8.424	8.424		126.360
Emergency capacity	0.000	0.000	0.000	0.000	0.000		0.000
Quarantine	0.000	0.000	0.000	0.000	0.000		0.000
Capital field equip	1.354	1.354	1.354	1.354	1.354		20.310
Publicity, research and training	0.846	0.846	0.846	0.846	0.846		12.694
Administration	1.693	1.693	1.693	1.693	1.693		25.388
Total	20.818	20.818	20.818	20.818	20.818		312.269

Table 15

Estimates of phased costs for medfly control programmes

SIT Suppression Tunisia zone 1		Year 1	2	3	4	5	.....	15 yr Total (US$ m)
Area of orchards (ha)	105000	SIT suppression		SIT suppression continues >>>>				
Multiple for non crop	4							
Total area (ha)	525000							

Costs per zone

Total costs (US$ millions)						
Traps	1.249	1.249	1.249	1.249	1.249	18.735
Fruit sampling	0.000	0.000	0.000	0.000	0.000	0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000	0.000
Bait spraying	1.092	1.092	1.092	1.092	1.092	16.380
Fly production	1.654	1.654	1.654	1.654	1.654	24.806
SIT release of flies	2.835	2.835	2.835	2.835	2.835	42.525
Emergency capacity	0.000	0.000	0.000	0.000	0.000	0.000
Quarantine	0.000	0.000	0.000	0.000	0.000	0.000
Capital field equip	0.546	0.546	0.546	0.546	0.546	8.196
Publicity, research and training	0.341	0.341	0.341	0.341	0.341	5.122
Administration	0.683	0.683	0.683	0.683	0.683	10.245
Total	8.401	8.401	8.401	8.401	8.401	126.009

Total cost for country

Total costs (US$ millions)						
Traps	1.249	1.249	1.249	1.249	1.249	18.735
Fruit sampling	0.000	0.000	0.000	0.000	0.000	0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000	0.000
Bait spraying	1.092	1.092	1.092	1.092	1.092	16.380
Fly production	1.654	1.654	1.654	1.654	1.654	24.806
SIT release of flies	2.835	2.835	2.835	2.835	2.835	42.525
Emergency capacity	0.000	0.000	0.000	0.000	0.000	0.000
Quarantine	0.000	0.000	0.000	0.000	0.000	0.000
Capital field equip	0.546	0.546	0.546	0.546	0.546	8.196
Publicity, research and training	0.341	0.341	0.341	0.341	0.341	5.122
Administration	0.683	0.683	0.683	0.683	0.683	10.245
Total	8.401	8.401	8.401	8.401	8.401	126.009

Table 16

Action plan for medfly control

BAIT Suppression Standard zone 1		Year 1	2	3	4	5	.....	15 yr Total (US$ m)
Area of orchards (ha)	100000	Bait application		Continued bait application >>>>				
Multiple for non crop	4							
Total area (ha)	500000							

Traps/ha	Units					
Orchards		0.02	0.02	0.02	0.02	0.02
Wild		0.002	0.002	0.002	0.002	0.002
Samples per year		26	26	26	26	26
Lab ID for traps (estimated flies/ha caught)						
Orchards		5	5	5	5	5
Wild		0.5	0.5	0.5	0.5	0.5
Fruit sampling/ha						
Orchards		0	0	0	0	0
Wild		0	0	0	0	0
Samples per year		0	0	0	0	0
Fruit sample analysis (kg/ha)						
Orchards		0	0	0	0	0
Wild		0	0	0	0	0
Samples per year		0	0	0	0	0
Quarantine (intensity x basic cost)						
Orchards		0	0	0	0	0
Wild		0	0	0	0	0
Operations per year		0	0	0	0	0
Bait spray						
Operations per year		10	10	10	10	10
SIT release (million flies/ha)						
Orchards		0	0	0	0	0
Wild		0	0	0	0	0
Operations per year		0	0	0	0	0

Table 17

Estimates of phased costs for medfly control programmes

BAIT Suppression Algeria zone 3		Year 1	2	3	4	5	.....	15 yr Total (US$ m)
Area of orchards (ha)	30000	Bait application		Continued bait application >>>>				
Multiple for non crop	8							
Total area (ha)	270000							

Costs per zone

Total costs (US$ millions)						
Traps	0.229	0.229	0.229	0.229	0.229	3.441
Fruit sampling	0.000	0.000	0.000	0.000	0.000	0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000	0.000
Bait spraying	3.240	3.240	3.240	3.240	3.240	48.600
Fly production	0.000	0.000	0.000	0.000	0.000	0.000
SIT release of flies	0.000	0.000	0.000	0.000	0.000	0.000
Emergency capacity	0.000	0.000	0.000	0.000	0.000	0.000
Quarantine	0.000	0.000	0.000	0.000	0.000	0.000
Capital field equip	0.278	0.278	0.278	0.278	0.278	4.163
Publicity, research and training	0.173	0.173	0.173	0.173	0.173	2.602
Administration	0.347	0.347	0.347	0.347	0.347	5.204
Total	4.267	4.267	4.267	4.267	4.267	64.011

Total cost for country

Total costs (US$ millions)						
Traps	0.688	0.688	0.688	0.688	0.688	10.324
Fruit sampling	0.000	0.000	0.000	0.000	0.000	0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000	0.000
Bait spraying	9.720	9.720	9.720	9.720	9.720	145.800
Fly production	0.000	0.000	0.000	0.000	0.000	0.000
SIT release of flies	0.000	0.000	0.000	0.000	0.000	0.000
Emergency capacity	0.000	0.000	0.000	0.000	0.000	0.000
Quarantine	0.000	0.000	0.000	0.000	0.000	0.000
Capital field equip	0.833	0.833	0.833	0.833	0.833	12.490
Publicity, research and training	0.520	0.520	0.520	0.520	0.520	7.806
Administration	1.041	1.041	1.041	1.041	1.041	15.612
Total	12.802	12.802	12.802	12.802	12.802	192.032

Table 18

Estimates of phased costs for medfly control programmes

BAIT Suppression Libya zone 1		Year 1	2	3	4	5	.....	15 yr Total (US$ m)
Area of orchards (ha)	50000	Bait application		Continued bait application >>>>				
Multiple for non crop	4							
Total area (ha)	250000							

Costs per zone

Total costs (US$ millions)						
Traps	0.297	0.297	0.297	0.297	0.297	4.461
Fruit sampling	0.000	0.000	0.000	0.000	0.000	0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000	0.000
Bait spraying	5.200	5.200	5.200	5.200	5.200	78.000
Fly production	0.000	0.000	0.000	0.000	0.000	0.000
SIT release of flies	0.000	0.000	0.000	0.000	0.000	0.000
Emergency capacity	0.000	0.000	0.000	0.000	0.000	0.000
Quarantine	0.000	0.000	0.000	0.000	0.000	0.000
Capital field equip	0.440	0.440	0.440	0.440	0.440	6.597
Publicity, research and training	0.275	0.275	0.275	0.275	0.275	4.123
Administration	0.550	0.550	0.550	0.550	0.550	8.246
Total	6.762	6.762	6.762	6.762	6.762	101.427

Total cost for country

Total costs (US$ millions)						
Traps	0.297	0.297	0.297	0.297	0.297	4.461
Fruit sampling	0.000	0.000	0.000	0.000	0.000	0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000	0.000
Bait spraying	5.200	5.200	5.200	5.200	5.200	78.000
Fly production	0.000	0.000	0.000	0.000	0.000	0.000
SIT release of flies	0.000	0.000	0.000	0.000	0.000	0.000
Emergency capacity	0.000	0.000	0.000	0.000	0.000	0.000
Quarantine	0.000	0.000	0.000	0.000	0.000	0.000
Capital field equip	0.440	0.440	0.440	0.440	0.440	6.597
Publicity, research and training	0.275	0.275	0.275	0.275	0.275	4.123
Administration	0.550	0.550	0.550	0.550	0.550	8.246
Total	6.762	6.762	6.762	6.762	6.762	101.427

Table 19

Estimates of phased costs for medfly control programmes

BAIT Suppression Morocco zone 4		Year 1	2	3	4	5	.....	15 yr Total (US$ m)
Area of orchards (ha)	30000	Bait application		Continued bait application >>>>				
Multiple for non crop	12							
Total area (ha)	390000							

Costs per zone

Total costs (US$ millions)						
Traps	0.280	0.280	0.280	0.280	0.280	4.206
Fruit sampling	0.000	0.000	0.000	0.000	0.000	0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000	0.000
Bait spraying	3.360	3.360	3.360	3.360	3.360	50.400
Fly production	0.000	0.000	0.000	0.000	0.000	0.000
SIT release of flies	0.000	0.000	0.000	0.000	0.000	0.000
Emergency capacity	0.000	0.000	0.000	0.000	0.000	0.000
Quarantine	0.000	0.000	0.000	0.000	0.000	0.000
Capital field equip	0.291	0.291	0.291	0.291	0.291	4.368
Publicity, research and training	0.182	0.182	0.182	0.182	0.182	2.730
Administration	0.364	0.364	0.364	0.364	0.364	5.461
Total	4.478	4.478	4.478	4.478	4.478	67.165

Total cost for country

Total costs (US$ millions)						
Traps	1.122	1.122	1.122	1.122	1.122	16.824
Fruit sampling	0.000	0.000	0.000	0.000	0.000	0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000	0.000
Bait spraying	13.440	13.440	13.440	13.440	13.440	201.600
Fly production	0.000	0.000	0.000	0.000	0.000	0.000
SIT release of flies	0.000	0.000	0.000	0.000	0.000	0.000
Emergency capacity	0.000	0.000	0.000	0.000	0.000	0.000
Quarantine	0.000	0.000	0.000	0.000	0.000	0.000
Capital field equip	1.165	1.165	1.165	1.165	1.165	17.474
Publicity, research and training	0.728	0.728	0.728	0.728	0.728	10.921
Administration	1.456	1.456	1.456	1.456	1.456	21.842
Total	17.911	17.911	17.911	17.911	17.911	268.661

Table 20

Estimates of phased costs for medfly control programmes

BAIT Suppression Tunisia zone 1		Year 1	2	3	4	5	.....	15 yr Total (US$ m)
Area of orchards (ha)	105000	Bait application		Continued bait application >>>>				
Multiple for non crop	4							
Total area (ha)	525000							

Costs per zone

Total costs (US$ millions)						
Traps	0.625	0.625	0.625	0.625	0.625	9.368
Fruit sampling	0.000	0.000	0.000	0.000	0.000	0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000	0.000
Bait spraying	10.920	10.920	10.920	10.920	10.920	163.800
Fly production	0.000	0.000	0.000	0.000	0.000	0.000
SIT release of flies	0.000	0.000	0.000	0.000	0.000	0.000
Emergency capacity	0.000	0.000	0.000	0.000	0.000	0.000
Quarantine	0.000	0.000	0.000	0.000	0.000	0.000
Capital field equip	0.924	0.924	0.924	0.924	0.924	13.853
Publicity, research and training	0.577	0.577	0.577	0.577	0.577	8.658
Administration	1.154	1.154	1.154	1.154	1.154	17.317
Total	14.200	14.200	14.200	14.200	14.200	212.996

Total cost for country

Total costs (US$ millions)						
Traps	0.625	0.625	0.625	0.625	0.625	9.368
Fruit sampling	0.000	0.000	0.000	0.000	0.000	0.000
Fruit sample analysis	0.000	0.000	0.000	0.000	0.000	0.000
Bait spraying	10.920	10.920	10.920	10.920	10.920	163.800
Fly production	0.000	0.000	0.000	0.000	0.000	0.000
SIT release of flies	0.000	0.000	0.000	0.000	0.000	0.000
Emergency capacity	0.000	0.000	0.000	0.000	0.000	0.000
Quarantine	0.000	0.000	0.000	0.000	0.000	0.000
Capital field equip	0.924	0.924	0.924	0.924	0.924	13.853
Publicity, research and training	0.577	0.577	0.577	0.577	0.577	8.658
Administration	1.154	1.154	1.154	1.154	1.154	17.317
Total	14.200	14.200	14.200	14.200	14.200	212.996

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