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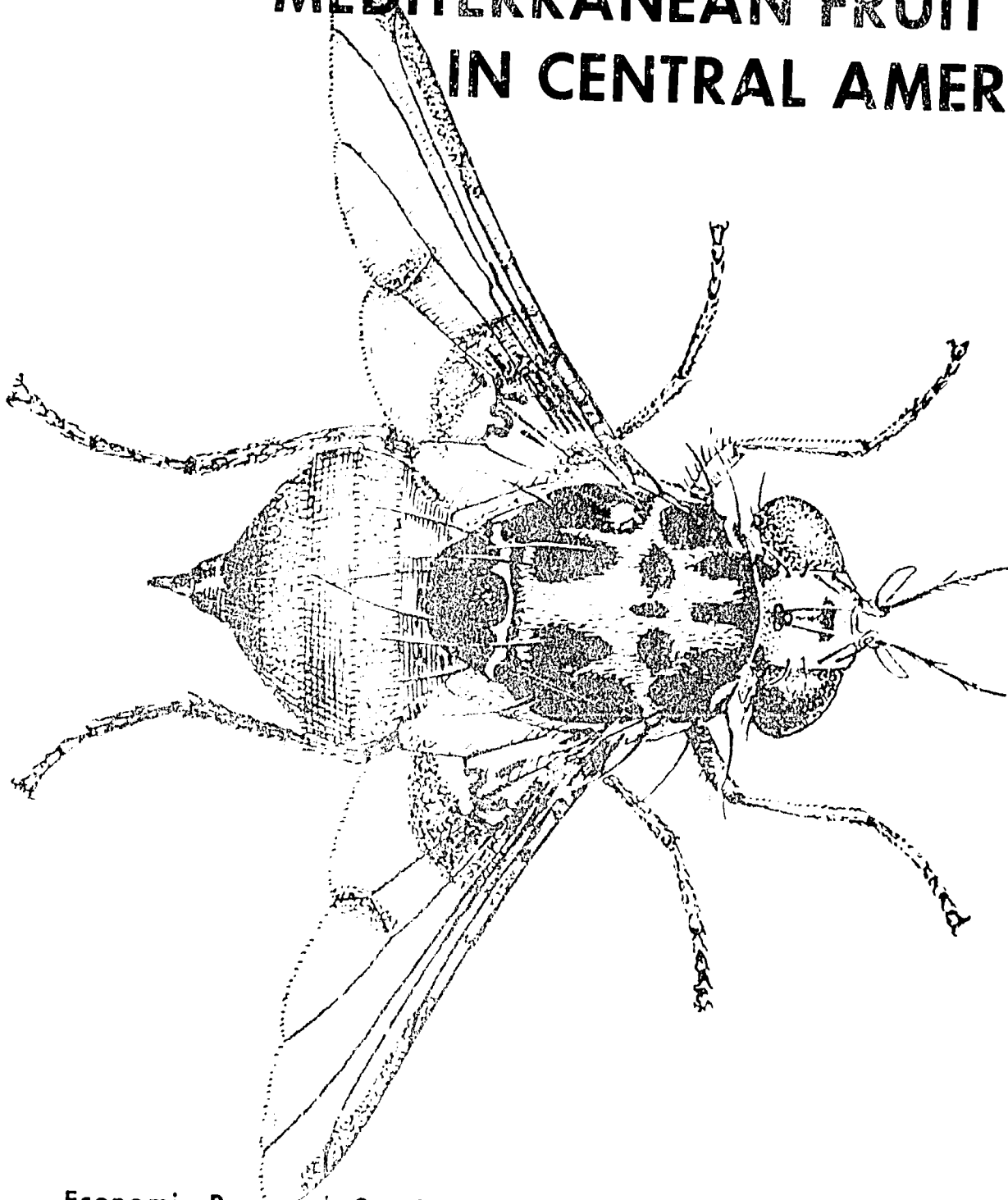
Field Report 21

Economic Survey of the MEDITERRANEAN FRUIT FLY IN CENTRAL AMERICA



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Economic Research Service, U.S. Department of Agriculture
cooperating with U.S. Agency for International Development

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An Economic Survey of the Mediterranean Fruit Fly in Central America

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The project has especially benefited from the assistance and attention given the team by Dr. Robert Rhode, United Nations Development Program Project Manager, in charge of the UNDP-Organismo Internacional Regional de Sanidad Agropecuaria medfly laboratory in San Jose, Costa Rica. He shared generously his experience with the OIRSA medfly program in Central America and his first-hand knowledge of the environment of the medfly. Information supplied by George Cavin, Animal and Plant Health Inspection Service, USDA, made it possible to arrive at realistic estimates of costs for spraying, fly release, survey, and quarantine operations.

SUMMARY AND RECOMMENDATIONS

SUMMARY

The Mediterranean fruit fly, Ceratitis capitata (Wied.), is established in coffee and fruit growing areas in Costa Rica, Nicaragua, and western Panama in Central America. While the medfly is established in areas of Nicaragua near the Honduras border, it is not found in Honduras or any other country north of Nicaragua.

In the absence of any control eradication program, the medfly can be expected to soon spread into Honduras, El Salvador, Guatemala, and subsequently into British Honduras and Mexico.

In areas in Central America* where the medfly is found, it apparently prefers ripe coffee cherries as hosts, followed by mandarins, grapefruit, and oranges. A large number of other tropical fruits are also hosts for the medfly, ranging from primary (preferred) to poor hosts.

In terms of economic damage, mandarins, grapefruit, and oranges are the principal victims. Also, medfly larvae can almost always be found in coffee cherries, but their presence does not appear to directly affect the commercial quality of the coffee bean. The stem and mesocarp of medfly-infested cherries are somewhat difficult to remove in coffee processing, so these cherries are thrown in with other sticktights for special treatment. The medfly-caused sticktights may approach the volume of sticktights usually occurring from other causes. The economic loss from the additional volume of sticktights would be reflected only in a slightly lower quality--from prime or export grade to domestic quality--at about 10 percent difference in price.

Since coffee production in Central American countries now generally exceeds the quantity which can be sold in domestic and export markets, little expansion of coffee production is feasible. Domestic consumption demand for coffee in the producing countries is quite inelastic. Exports are limited principally by commercial or institutional factors (of which the International Coffee Agreement is important) and not by lack of supplies (production) or by poor quality. In a program to control or eradicate the medfly, however, it would be necessary to spray or treat all coffee in the area because of the importance of coffee as a host to the medfly.

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*In this report, "Central America" includes the countries of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama.

In the absence of published data, approximations of fruit production and value in Central America were developed for 1970 based on the few data that were available, impressions or estimates of persons familiar with the area, and personal observations and impressions of the survey team. The estimates include all fruit produced in the Central American countries, consumed or exported, including naturally-occurring and dooryard plantings, as well as commercial production.

The total production of fruits, melons, and tomatoes, which at first glance appeared subject to medfly damage in Central America, was estimated at about 3.4 million tons for 1970, worth $308.2 million. About four-fifths of this production was found not to be susceptible to medfly damage in the field, however. Commercially-important crops not attacked by the medfly include bananas (by far the largest volume and grown primarily for export), pineapples, watermelons, cantaloupe, tomatoes, and other vegetable crops.

Estimated Central American production of all fruits susceptible to attack and damage by the medfly totaled 638,000 tons in 1970, with a value of $58.2 million. Of these, 338,000 tons, worth $25 million, were citrus fruits.

Direct losses of fruit due to the medfly in infested areas in Central America were estimated at roughly 28 percent for sweet oranges, 50 percent or more for mandarins, 24 percent for grapefruit, a nominal 2 percent for other susceptible fruit, and, indirectly, 1 percent for coffee.

The dollar value of direct crop loss (citrus and other tropical fruits) due to the medfly in Central America is estimated at about $4 million a year currently, and can be expected to increase proportionately with any increase in fruit production. Generally, it is assumed that fruit production will increase at a slightly faster rate than human population.

Because of the extensive area which would need to be treated, any program to eradicate the medfly in Central America would be costly. The maximum total cost of an eradication program using sterile fly release to the extent feasible, including costs of an intensive monitoring program, would approximate $31 million over a 6-year period.

However, cumulative benefits (fruit losses avoided) from eradication of the medfly in presently-infested areas in Central America would approximate the costs of eradication by the seventh year, and exceed them in the eighth year. Benefits would exceed costs as early as the fifth year if you assume the medfly would spread to other areas in the absence of an eradication program, leaving a positive balance of about $15 million each year after that. Also, with the eradication of medfly in these countries, there would be no need for local control efforts or spraying of private groves for the medfly; thus, costs for these activities would not occur in the future.

The cost of a similar eradication program using insecticide (malathion) plus bait sprays in areas suitable for low-level air application would be somewhat less ($25.6 million), but would have a greater impact on other insects and the environment. A program using air application of ULV malathion, where feasible, would cost an estimated $21.8 million, but would have a still greater impact on other insects and the environment; besides, it has not yet been proven completely effective for such an eradication program.

In addition to the direct treatment costs, any type of eradication program should be preceded and followed by a survey trapping program throughout all Central American countries to detect existing, persisting, and new infestations of the medfly and other insect pests. An intensive monitoring program in the treatment area during the period of treatment is necessary for effective execution of any eradication program and to determine when eradication has been achieved.

The survey trapping program should be conducted throughout Central America whether or not eradication of the medfly is attempted, and should include trapping of other insect pests. The monitoring program, included as a separate cost item in the suggested eradication program, would probably result in lower costs of treatment and, thus, could be partly or completely self-liquidating.

RECOMMENDATIONS

1. Strengthen quarantine program in Central America as a first line of defense against further spread of the medfly and other insect pests.

2. Establish a permanent, comprehensive trapping program to survey for the presence, and measure the population density of the medfly and other insect pests.

3. Eradication of the medfly in Central America appears to be feasible, and should be considered. Total estimated costs of such a program would be covered by estimated benefits in 5 to 7 years. After eradication, only survey trapping and quarantine programs would be needed, plus possibly occasional eradication of a local reinfestation.

4. Research on the Mediterranean fruit fly in Central America should be continued to improve or develop new methods of control or eradication. This should include both chemical and biological control methods. Also,

new methods of survey for detection of the medfly or its host plant distribution, including the possible use of remote sensing, should be investigated and tested.

Further investigation in the biology of the medfly and its climatic and host requirements are implicit in any research activity, in order to implement more effective control.

INTRODUCTION

ANTECEDENTS

This study resulted from a series of conferences among officials of the U.S. Agency for International Development (AID), the U.S. Department of Agriculture (USDA), United Nations Development Program (UNDP), the International Atomic Energy Agency (IAEA), Regional Organization for Central America and Panama (ROCAP), and Organismo Internacional Regional de Sanidad Agropecuaria (OIRSA) since December 1970. Increased spread of the medfly in Costa Rica and Nicaragua and the growth of commercial and tourist travel throughout Central America resulted from completion of the Pan American Highway to Panama and the new network of feeder roads connecting the Central American Common Market countries. Improved prospects for completion of the Darien Gap section of the Pan American Highway introduced the possibility for even greater and more rapid distribution of the insect. If any consideration were to be given to eradicating the medfly from Central America, the matter had to be studied before further spread took place.

Another reason for conducting a survey at this time is that, in 1967, AID financed an extensive fruit fly eradication campaign in Central America and, desiring to avoid the problems encountered at that time, sought to have a thorough up-to-date study.

The importance of medfly to the agriculture of the countries where it already exists, as well as the undesirability of its spread to new countries, were additional reasons for undertaking the study.

OBJECTIVES AND PROCEDURES

The principal objectives of this AID-sponsored study were (1) to determine the present damage caused by the Mediterranean fruit fly in Central America and also the potential damage if it were to spread to previously infested areas, and (2) to estimate the cost of eradicating the medfly, along with the benefits which would be attributable to such eradication.

Because of the broad scope of factors to be examined in the study, a 4-man team was formed which included specialists in entomology, tropical horticulture, agricultural marketing, and agricultural economics. In addition, Dr. Robert Rhode, the resident manager of the UNDP-OIRSA medfly laboratory in San Jose, Costa Rica, contributed substantially to the study.

A dominant feature of the Mediterranean fruit fly in Central America is the paucity of data and information regarding characteristics and habits of the fly and its hosts in the Central American environment. Consequently, substantial efforts were made by the study team to collect and evaluate available data, and to develop estimates where data were not available. This required two personal visits to each of the Central American countries. The first was in November and December 1971, the period when the medfly population was at its seasonal low point. The second visit was in February and March 1972, when the medfly population was at its seasonal high.

Finally, the team, including Dr. Rhode, convened in Washington in late April to coordinate the findings of the individual team members for preparation of the summary report.

BIOLOGY AND DISTRIBUTION OF THE MEDFLY

ENVIRONMENTAL CONDITIONS AFFECTING THE REPRODUCTION AND PERSISTENCE OF THE MEDFLY

Climate

The climate of Central America is generally subtropical, with considerable variations in elevation, rainfall, and average temperatures. Elevation ranges from sea level to 12,000 feet or more, with a range of mountains generally dividing the Central American isthmus longitudinally.

On the Pacific side, where the human population of the region is concentrated, the year is divided into definite rainy and dry seasons. The rainy season generally begins in April and extends into November. Little rain falls during the remaining months. On the Atlantic, or Caribbean side of the isthmus, rainfall occurs throughout much of the year and there is a less definite dry season.

Many fruit species occur naturally or are cultivated throughout Central America, from sea level to elevations of 6,000 feet or more. Between 1,500 and 5,000 feet, coffee, a primary host of the medfly, is grown extensively. Many fruits, especially citrus, which also grow in this zone are likewise hosts of the medfly.

Cool night temperatures may inhibit fly development in the higher elevations, but, in warmer seasons, the fly should be able to move up, especially when host fruits are available. Deciduous and citrus fruits growing at these higher elevations can be expected to be infested when the main coffee crop has been harvested and the fly moves to alternate hosts. At the lower elevations, from sea level to 3,500 feet, peaches, citrus, and other subtropical fruits are commonly infested in the cooler, dryer months.

Rainfall appears to be a factor in inhibiting pupal development in the soil, as pupae mortality is exceptionally high in wet soil. As the rainy season begins, incidence of fly infestation in the coffee rapidly diminishes, to almost zero by July. As the season becomes dry in November, fly population begins building up in the maturing coffee, reaching a maximum in late February or March, roughly coinciding with coffee harvest. Then, the medfly moves to nearby citrus, other subtropical fruits, peaches, and apricots which normally are also maturing during this same period. These other fruit hosts provide a means for carryover of the medfly to the new maturing coffee.

Hosts and Host Preferences

About 200 fruits and some vegetables are attacked by the medfly, some rarely while others are heavily infested. Primary hosts are coffee, citrus, mango, rose apple, plums, peach, apricot, and tropical almond. Variable reports have been given regarding the hosts preferred by the medfly in the three infested Central American countries. The evaluation by Ing. Orlando Astacio (Ministry of Agriculture--OIRSA Coordinator, Nicaragua) is believed to be relatively accurate and representative. He lists coffee, peaches, mandarin, grapefruit, oranges, and tropical almond. Coffee is preferred to mandarin when the two crops overlap. A detailed discussion of host preferences is presented in Section IV of this report.

GEOGRAPHIC DISTRIBUTION

Countries known to be infested by the medfly in Central America include Nicaragua, Costa Rica, and western Panama. In general, infestations are in developed areas where coffee and citrus are grown, or in towns with tropical almond and mixed fruit plantings (see Figure 1 and Tables 1 and 9).

Trapping operations during February-March 1972 confirmed previous information on the presence of the medfly. Trapping in El Salvador, Guatemala, and along the Nicaragua border and coffee-citrus areas in Honduras failed to disclose the presence of the medfly in these countries. Areas of similiar environment and fruit cultures--but still outside the area now infested--are subject to becoming infested, however.

The rate of medfly migration is not definitely known. However, its spread up to 300 miles throughout Costa Rica, Nicaragua, and western Panama within 10 years after its discovery near San Jose, Costa Rica, in 1955 indicates the rate of movement which could be expected. With the exception of high mountain ranges and extensive deserts, movement by normal fly drift or by air currents would be expected. Natural movement of several kilometers a year would appear reasonable in areas where there is fruit suitable for oviposition and development of larvae. In periods of dry weather or fruit shortage, flies move around in search for food, moisture, and oviposition media.

Also, the medfly could be carried longer distances by commercial or tourist travel from infested areas. This is probably the principal means of spread. Ignorant of the danger, people will carry fruit from infested to uninfested areas. Others will smuggle the fruit and discard it carelessly when they find it infested. Flies also move as hitchhikers in transportation vehicles or as larvae or pupae which settle in cracks and crevices of these vehicles.

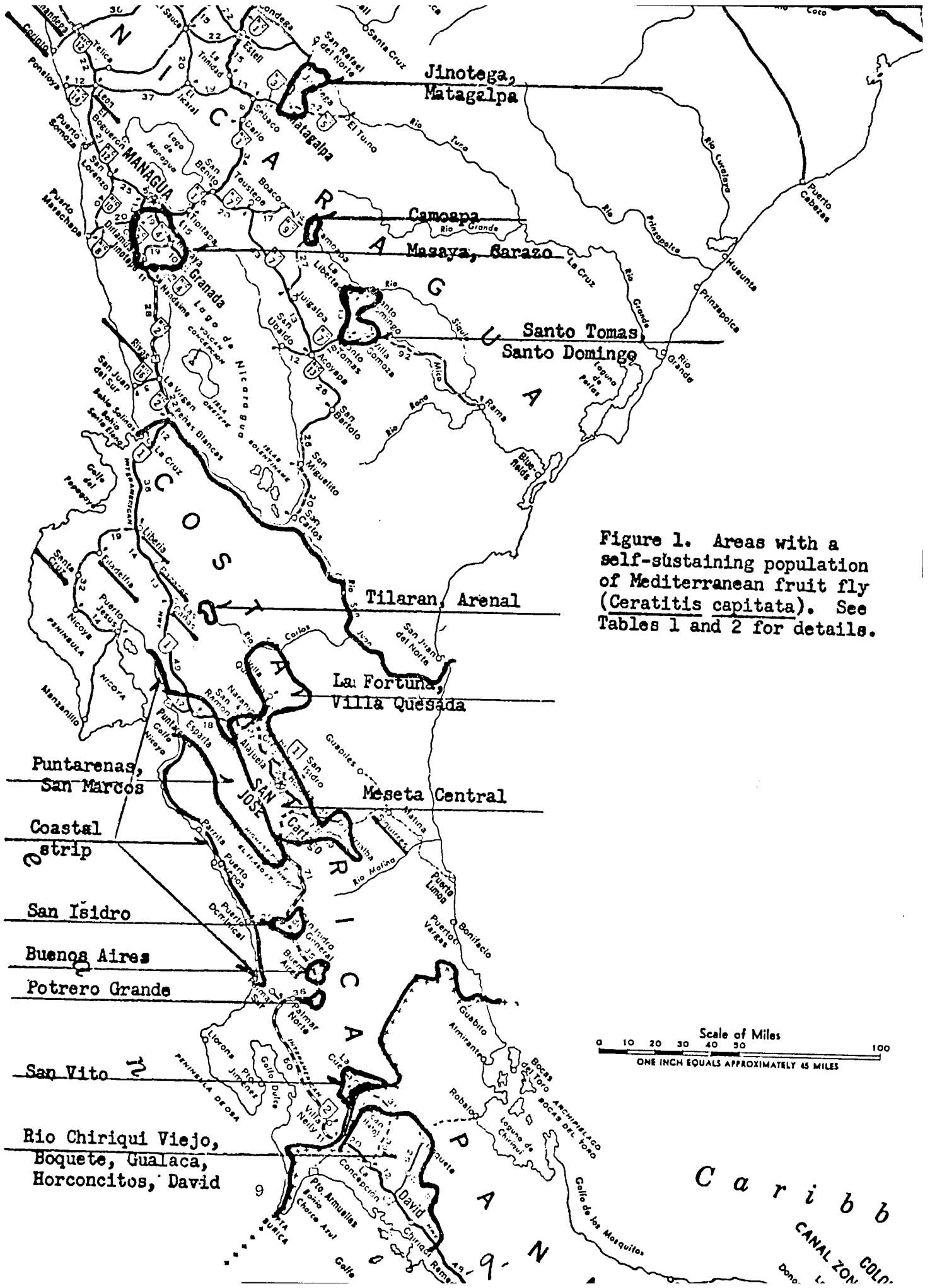

Figure 1. Areas with a self-sustaining population of Mediterranean fruit fly (Ceratitis capitata). See Tables 1 and 2 for details.

Table 1. Estimated size of areas supporting a self-sustaining population of Mediterranean fruit fly (*Ceratitis capitata*).

Country and district	Infested area: Mean dimensions in km. width	length	Square km.	Acres	Square miles	Percent of: Total C.A. infested area	country area [1]
Nicaragua:							
Matagalpa, Jinotega	11.0	27.0	297	73,390	114.7	2.8	0.20
Camoapa	3.8	7.5	29	7,042	11.0	.3	0.02
Santo Tomas, La Libertad, Santo Domingo	18.0	30.0	540	133,436	208.5	5.0	0.36
Masaya-Carazo	15.8	51.0	806	199,117	311.1	7.5	0.54
Subtotal [a]			1,672	412,985	645.3	15.5	1.13
Costa Rica:							
Tilaran, Arenal	14.0	18.0	252	62,270	97.3	2.3	0.50
La Fortuna, Pital, Rio Cuarto, Villa Quezada	24.0	36.0	864	213,498	333.6	8.0	1.70
Mesteta Central; San Ramon, Heredia, Cachi, Turrialba, Moravia, San Jose	30.0	96.0	2,880	711,660	1,112.0	26.7	5.68
Puntarenas, San Mateo, San Marcos	16.0	86.0	1,376	340,015	531.3	12.8	2.71
Valle de General; San Isidro de General	12.0	20.0	240	59,305	92.7	2.2	0.47
Buenos Aires	14.0	20.0	280	69,189	108.1	2.6	0.55
Potrero Grande	9.0	22.0	198	48,927	76.4	1.8	0.39
San Vito, Sabalito	14.0	20.0	280	69,189	108.1	2.6	0.55
Coastalstrip; Manzanillo-Puerto Cortes	3.0	210.0	630	155,676	243.2	5.9	1.24
Subtotal [a]			7,000	1,729,729	2,702.7	65.0	13.81
Panama:							
Rio Chiriqui Viejo, Cerro Purita, Bajo Boquete, Gualaca, Horconcitos, David	27.3	77.0	2,102	519,512	811.7	19.5	2.78
Grand total [a]			10,774	2,662,226	4,159.7	100.0	3.93

[a] Some of the individual items may not add to totals due to rounding.

[1] Total country area according to Hammond Atlas, 1971 ed.; Doubleday and Co., Inc.; Garden City, New York; 288 p.

The present vegetation and terrain of the Darien Peninsula do not appear favorable for rapid movement of the medfly into or through this area. With the completion of the Pan American highway through the Darien Peninsula, however, vehicular traffic between Panama and Colombia will present the possibility for more rapid movement of the fly between fruit and coffee areas in Central and South America. Increased settlement along the highway, with accompanying dooryard and commercial fruit and coffee planting, will also present much more favorable conditions for natural movement of the fly. Consequently, rigorous quarantine and survey trapping programs along the new highway will be essential. This program must be in operation when the highway is opened.

OTHER FRUIT PESTS IN CENTRAL AMERICA

Besides the medfly, other tropical fruit flies, primarily of the group *Anastrepha*, are widely distributed in Central America. The Mexican fruit fly, *Anastrepha ludens* (Loew), is generally found in areas north of the medfly-infested area, where it is a serious pest of citrus. *A. ludens* was not observed in fruit plantings where the medfly was established.

Other *Anastrepha* species found in medfly-infested areas were *A. mombinpraeoptans*, principally found in mango and mombin, and *A. striata*, commonly seen in guava. Papaya fruit fly, *Toxotrypana curvicauda*, is the principal pest of papaya.

Like the medfly, the other tropical fruit flies are effectively controlled by malathion sprays. Because the hosts (and, thus, geographic ranges) of the other fruit flies differ from those of the medfly, eradication of the medfly in Central America would not result in eradication of other fruit flies. An effective spray program would probably eliminate all fruit flies from the sprayed area, but *Anastrepha* and others having a more extensive distribution would drift into treated areas later. A medfly sterile fly release program, if effective, would eradicate only the medfly and would not directly affect other fruit fly species. Thus, eradication of the medfly from Central America would have only temporary, if any, direct impact on other fruit fly species. Other insect pests, including scale, aphids, fruit moth, etc., are present in fruit (citrus) groves in Central America. It could be expected that a spray program to eradicate the medfly would kill off many parasites and predators of these other insect pests.

EFFECTS OF THE MEDFLY ON THE CULTURE AND PRODUCTION OF FRUITS IN CENTRAL AMERICA

The Mediterranean fruit fly is a pest whose secondary influence is often greater than its primary damage. Medfly always limits the choice of fruit crops to a far greater degree than climatic requirements alone, the alternative being a considerable reduction in crop value and net return.

The puncture, egg cavity, and subsequent larval activities caused by the medfly open the way for fungi and bacteria. These, in turn, induce fruit decay that may occur either before or after the fruit is harvested. One fruit rotting in a container filled with healthy fruit can result in extensive damage to the entire lot.

Further, the presence of medfly in a country limits the number of good or prospective markets for its fruits. The stringent fruit fumigation requirements imposed by the United States to prevent the introduction of fruit flies reduces the holding capability or "shelf life" of the fruits so treated. Fruits processed and marketed frozen or canned, in slice, chunk, or juice form, must be free of larvae and larvae mouth hooks. This creates an additional cost to the producer for inspections and, in the case of juice, expensive equipment to insure against mouth hooks in the final product.

SUSCEPTIBILITY OF FRUITS TO MEDFLY ATTACK

The amount of primary damage to fruit caused by the medfly in an area is variable. It depends on climatic conditions and horticultural considerations. A high fly population in an area with mixed host plantings with fruit maturing over a long time period will result in the greatest fruit loss. This loss may be due to larval activity or repreated ovipositing attempts. While these ovipositing attempts are not successful in establishing a larval colony, they may render the fruit unsightly because of the host fruit surface reaction to the ovipositing wounds.

Climate affects the yearly differences and trends in fly populations. Vagaries of the weather, efficiency of the fruit as a host, the fruit maturation sequence, and the number and kinds of host fruits grown determine to a large measure the seasonal shifts in the fly population in an area. Each fruit selection, therefore, affects the fly differently depending on its ability to support the biological cycle of the fly and its interaction with climate and weather in terms of number of fruits produced, color development, and maturation. Growing conditions that induce

premature coloring and softening of fruits (i.e., drought, poor soil, incipient nutrient deficiencies, etc.) attract fruit fly oviposition. Different species react differently to the same set of environmental conditions; in mixed plantings, the picture is further confounded.

Host fruits, by the nature of their epidermis, their physiological reaction to ovipositing and the egg cavity, and the nature of their internal structure, govern the number of eggs deposited, the number of larvae that reach the pupal stage, and the length of time the fly is in the larval stage. The greatest number of larvae reach the pupal stage when eggs are deposited in ripe to overripe and partially decayed fruits. This is because "dead" ripe fruit have (1) a softened epidermis which is less resistant to puncture, (2) a breaking up, checking, or crazing of the cutin (waxy) covering on the epidermis, (3) "dried-up," nonfunctional subepidermal laticifers, (4) greatly reduced meristematic activity (gum secretions, wound periderm formation, etc.) due to physiological aging of the epidermis and subepiderma cells, and (5) a lysis, partial lysis, or other chemical changes in cells and cell wall structures which render the fruit more suitable to larval penetration and feeding. The latter may require the aid of secondary organisms to make some fruits suitable for successful completion of the larval stage (i.e., banana, sour lemon, sour lime, mammey apple, cotton bolls, etc.). The number of larvae that do successfully complete the larval stage in these fruits is extremely small.

APPARENT RELATIVE HOST FRUIT PREFERENCE

The term "host fruit preference" is often used to mean the relative capability of fruit selections to support the biological cycle of the medfly. A host fruit that yields a high ratio of pupae to eggs, or adults to eggs (1:1 would be perfect), is considered a "preferred" host by the fly. No published data shows experimental evidence of host preference *per se*. Inferences to host preferences are drawn from subjective field observations or limited cage tests. The latter, involving different selections of mangos, bananas, sour lemons, etc., at different stages of maturity are essentially tests of fruit susceptibility to medfly attack; they are not, nor are they purported to be, behavioral tests of preference.

The number of host fruits for the medfly, determined by field observation and laboratory cage tests, exceeds 200, and includes nearly all trees, shrubs, and vegetables that are of economic importance to man.

The following table lists hosts which have been observed in Central America. They are found growing together in various combinations in mixed plantings, or within easy flight of one another. This is not to say that all will be found in the same local area, but that enough are grown close enough for them to interact to influence the medfly population.

The fruits are listed and discussed in the order in which they are hosts for medfly in Central America, from primary to poor hosts. "Primary host" is used to indicate those that are frequently infested, produce a high pupae to egg ratio, and have a high number of fruits infested per plant. Primary hosts are given a letter "A" after the method of Back and Pemberton. The term "secondary host" is used to indicate hosts that are frequently infested and have a high number of fruits infested per plant, but have a somewhat low production ratio of pupae to eggs. Secondary hosts are given a letter "B." A "tertiary host" is one that is only occasionally a host, usually only in cage tests; results in a low production ratio of pupae to eggs; and has a low number of fruits infested per plant. Tertiary hosts are given a letter "C." A "poor host" is one which is rarely infested, usually only in cage tests; produces a very low pupae to egg ratio; and has only overripe, cracked, or partially decaying fruits infested. Poor hosts are given a letter "D." Table 2 lists these hosts.

Primary Hosts, A

Tropical almond, A, (*Terminalia catappa* L.)

This tree is used for ornamental purposes, principally shade, throughout Central America. It fruits the year around at low elevations and is one of the most likely sources of medfly. It constitutes the primary reason for medfly in the coastal strip from Manzanillo to Puerto Cortes in Costa Rica. It is particularly abundant as a dooryard tree both in and out of the medfly-inhabited areas. It thereby constitutes a serious threat by providing an excellent host for flies developing from medfly larvae-infested fruit that is thoughtlessly discarded in non-medfly areas. Fruits of the tropical almond are possibly the greatest single factor that explains the ability of the medfly to establish itself in the outlying communities noted in Figure 1 and Table 9.

Table 2. Hosts of Mediterranean fruit fly observed in Central America.

	Host Class and Common Name	Scientific Name a/
	Primary hosts, A	
1.	Tropical Almond	*Terminalia catappa*
2.	Coffee	*Coffea* spp.
3.	Rose Apple	*Eugenia jambos*
4.	Star Apple	*Chrysophyllum cainito*
5.	White Sapote	*Casimira edulis*
6.	Fig	*Ficus carica*
7.	Soursop	*Annona muricata*
	Cherimoya	*Annona cherimolia*
	Sweetsop	*Annona squamosa*
8.	Loquat	*Eribotrya japonica*
9.	Pitanga	*Eugenia uniflora*
10.	Barbados Cherry	*Malpigha glabra*
11.	Natal plum	*Carissa grandiflora*
12.	Peach	*Prunus Persica*
13.	Apple	*Malus sylvestris*
	Pear	*Pyrus* spp.
	Quince	*Cydonia oblonga*
	Apricot	*Prunus Armeniaca*
	Sweet Cherry	*Prunus avium*
	Sour Cherry	*Prunus Cerasus*
	Secondary hosts, B	
14.	Mandarin	*Citrus reticulata*
15.	Sour Orange	*Citrus reshni*
16.	Sweet Orange	*Citrus aurantium*
17.	Grapefruit	*Citrus sinensis*
18.	Shaddock	*Citrus paradisi*
19.	Plum	*Citrus grandis*
		Prunus spp.
	Tertiary hosts, C	
20.	Mangos	*Mangifera indica*
21.	Red mombin	*Spondias purpurea*
	Yellow mombin	*Spondias mombin*
22.	Papaya	*Carica papaya*
23.	Guava	*Psidium guajava*
24.	Avocado	*Persea americana*
25.	Carambola	*Averrhoa carambola*
26.	Strawberry	*Fragaria virginiana* x *chiloensis*
27.	Tomato	*Lycopersicon esculentum*

Table 2. Hosts of Mediterranean fruit fly observed in Central America (cont'd)

	Host Class and Common Name	Scientific Name a/
	Tertiary hosts, C (continued)	
28.	Sweet peppers	*Capsicum annuum* var. *grossum*
	Chillies	*C. annuum* var. *acuminatum*
29.	Cucumber	*Cucumis sativus*
30.	Cactus fruits	*Opuntia vulgaris*
		Opuntia ficus indica
		Other cactus genera
	Poor hosts, D	
31.	Sour lime	*Citrus aurantifolia*
	Sweet lime b/	*Citrus limettioides*
32.	Sour lemon	*Citrus limon*
	Rough lemon	*Citrus jambhiri*
33.	Bananas	*Musa* spp.
34.	Grape	*Vitis labrusca*
		Vitis vinifera
35.	Passion fruit	*Passiflora* spp.
36.	Mammey apple	*Mammea americana*
37.	Sapodilla	*Manilkara achras*
38.	Cashew	*Anacardium occidentale*
39.	Breadfruit	*Artocarpus altilis*
40.	Jackfruit	*Artocarpus heterophyllus*
41.	Pomegranate	*Puncia granatum*
42.	Naranjilla c/	*Solanum quitoense*
43.	Egg plant	*Solanum melongena*
44.	Chayote	*Sechium edule*
45.	Watermelon	*Citrullus lanatus*
46.	Melon	*Cucumis melo*

a/ Latin binomials according to: J. W. Purseglove, 1968, Tropical Crops, Dicotyledons, 2 vol., John Wiley & Sons, Inc., New York, 719p and J. H. Gourley and F. S. Howlett, 1955, Modern Fruit Production, The Macmillan Co. New York, 579.

b/ Not observed in Central America, but it is on host lists as subject to field infestation by medfly.

c/ Host status unknown. Not found infested.

Coffee, A (principally Coffea arabica L. var. arabica, C. arabica var. bourbon (B. Rodr.) Choisy, C. conephora Pierre ex Froehner)

Coffee is the single most important commercial crop sustaining the major medfly infestations in Central America. This is because coffee is an exceptionally good host for the fly, and there is a year-round source of fruit for oviposition from trees in off-bloom and scattered cherries left from incomplete harvest. The main season of maturation, when some coffee fruits are bright red, begins in June-July and ends in February-March. This is a period of 8 to 10 months with no interruption, except for peak harvest periods in November-December.

Harvesting according to color puts emphasis on removing the ripe and over-ripe fruits. These are also the fruits carrying medfly eggs and larvae. Hence, a thorough harvest in November and December, occurring at the same time throughout an area, would help considerably in reducing the medfly density throughout the remainder of the medfly season. The medfly season ends 3 to 5 weeks following the first heavy rains commencing in April-May.

The only detailed study of the effect of medfly on coffee production was made in Hawaii by Back and Pemberton in 1918. They reported a 27 to 59 percent loss in fresh weight when the medfly infested 55 to 60 percent of the coffee cherries.

In the Hawaii study, 15 to 23 percent of the medfly-infested fruit failed to pulp, compared to 8 to 13 percent of the noninfested fruit, indicating that some 7 to 10 percent more fruit failed to pulp because of the medfly.

Four small lots of infested fruit were compared with similar lots of non-infested fruit in the 1918 study. The effect of medfly larvae activity in the fleshy mesocarp had no significant effect on the dry weight of the finished beans produced. Two infested lots showed 2 to 3 percent dry weight loss, but there was no reduction in the other two lots. The average dry weight loss was 1.256 percent, but this is well within sampling error.

Fruit losses in the field because of fruit drop in Central America are only speculative. Fruit drop of medfly-infested fruit occurs after the mesocarp is thoroughly decimated by the larvae and has dried (the larvae have already dropped to the soil to pupate). Even then fruit abscise only during and immediately following a heavy rain. Such heavy rains seldom occur at the appropriate time to cause medfly-infested fruit to drop.

As the coffee harvesting season progresses after December, the total crop volume decreases while the medfly-induced coffee cherry drop increases. The total seasonal volume of loss of coffee due to the medfly has not been critically evaluated, but it is estimated roughly at from 3 to 8 percent, and a mean value at 5 percent appears to be realistic.

Rose apple, A, (Eugenia jambos L.)

Rose apples are used as windbreaks for coffee and as scattered dooryard fruit trees. Generally they are considered a primary host for medfly; however, in the Carazo area south of Managua, Nicaragua, it is only lightly infested.

Star apple, A, (Chrysophyllum cainito L.)

Star apples are grown in scattered dooryard plantings, with occasional trees seen in coffee, citrus, and other plantings. The fruit is an extremely good host to medfly, but is only successfully infested when the fruit is overripe. Until overripe, the fruit exudes a latex which floods small punctures and abrasions.

White sapote, A, (Casimiroa edulis La Llave & Lex.)

White sapote is grown in scattered locations. Infestation generally begins when the fruit starts to ripen since a white sap floods small punctures and abrasions until then.

Fig, A, (Ficus carica L.)

Figs are grown in scattered locations and in dooryard plantings. The fruit is not infested until thoroughly ripe and ready to eat, as the fruit exudes copious quantities of latex from punctures and abrasions until it is dead ripe. Fruits grown in high medfly density areas are eaten with many small larvae present. The flower buds obscure the presence of the larvae.

Soursop, A, (Annona muricata L.); cherimoya, A, (Annona cherimolia Mill.); sweetsop or sugar apple, A, (Annona squamosa L.)

These are grown as dooryard trees in mixed plantings, with an occasional tree found in or near plantings of coffee or citrus or both. They are readily infested by medfly after they are ripe to overripe.

Loquat, A, (Eriobotrya japonica Lindl.)

Very few trees are grown. They are found as individuals mixed in a windbreak, hedgerow, or dooryard planting. Trees observed were 5 to 10 meters in height, with the fruit seldom harvested. Ovipositing punctures are readily visible, as the area around the puncture remains greener as the fruit ripens.

Pitanga or Surinam cherry, A, (Eugenia uniflora L.)

One shrub was observed in the Carazo area of Nicaragua. Fruits were generally infested. Reports from Florida, Hawaii, etc., indicate that it is an exceptionally good host, although the yield of adult flies per infested fruit is low.

Barbados cherry, A, (Malphigphia glabra L.)

No shrubs were observed but it is listed here because it is an extremely rich source of ascorbic acid and has received much popular acclaim from time to time over the past 10 years. It is native to the area from northern South America to the southern border of the United States. It is a primary host and often heavily infested by medfly.

Natal plum, A, (Carissa grandiflora A. DC.)

It is seen occasionally in ornamental gardens in all of the capital cities, but rarely in outlying areas. It was not seen infested; however, it is reported to be a primary host, even though the fruit is only successfully infested when fully ripe to overripe. The fruit exudes a latex-like sap that floods small punctures and abrasions even when the fruit is fully colored.

Peach, A, (Prunus Persica Sieb. Zucc.)

Scattered dooryard peaches are grown in the highlands of Central America. Where peaches are grown, tropical almond fails to fruit well. Hence, the dooryard peach constitutes a hazard because it matures early in the season; and, also the medfly can successfully infest it prior to full fruit maturity. Excellent examples of the role it plays in sustaining the medfly population by being "available" early in the dry season are the medfly-infested towns of Jinotega, Nicaragua, and Boquete, Panama.

The extent of medfly damage on peaches was not evaluated in this study; however, Baas in 1959 (Central Europe) reported average yield losses of 10 to 50 percent for early peaches, and 100 percent crop losses in late peaches.

Apples, A, (Malus sylvestris Mill)
Pear, A, (Pyrus spp., principally P. communis L.)
Quince, A, (Cydonia oblonga (L.) Mill)
Apricot, A, (Prunus Armeniaca L.)
Nectarine, A, (P. Persica var. nectarina)
Sweet cherry, A, (P. avium L.)
Sour cherry, A, (P. Cerasus L.)

These are primary hosts; however, their culture is very limited or virtually nonexistent in Central America. Very minor apple production is reported in the northwest highlands of El Salvador. Guatemala has a few plantings of apples, pears, quince, and cherries. Costa Rica expressed interest in starting a small industry of apples and pears, just enough to offset its imports.

The cooler climates of the highlands are no insurance against medfly infestation. Baas in 1959 reported average apple yield losses in Central Europe were 2 to 10 percent for several varieties, with 100 percent losses in one variety. Average cherry and apricot yield losses were 80 to 100 percent. In 1951 in Israel, Bodenheimer reported an average of 30 to 60 percent infestation of late apricot varieties, with little or no losses to early apricot varieties.

There are no quantitative reports of yield losses for quince and nectarines, but reports from South Africa, Australia, and Hawaii for these fruits, along with reports from Israel for quince and pears, indicate that losses due to medfly infestations can be substantial. In Israel, pears sustained a 15 to 90 percent loss due to medfly attack, depending on variety.

The softer varieties of apples and pears suffer the greatest yield losses. Only apricots, nectarines, and cherries that are harvested early in the season before the medfly population is high escape severe infestation. When medfly population density is high early in the season, usually because of a milder, drier-than-normal winter supported by a suitable host fruit sequence the previous year, none escape infestation.

Secondary Hosts, B

Mandarin or tangarine, B, (*Citrus reticulata* Blanco cv. 'Ponkan,' 'Clementine,' 'Dancy,' and 'Satsuma,' also *C. reshni* Hort. ex Tan. cv. 'Cleopatra')

Mandarins are grown throughout Central America in orchards of 100 to 300 trees, as interplants providing partial shade to coffee, and in door-yard plantings. The selections grown have a thin rind with a loose albedo, the segments are easily separated, juice vesicles are not tightly packed, juice vesicle cell walls are tender, and the fruit develops an excellent varietal color at maturity.

Mandarins, with Ponkan the dominant variety, are particularly vulnerable to medfly attack. The excellent color at maturation induces the medfly to oviposition, and the thin, loose rind allows the placement of eggs between the loose albedo and the somewhat tender segment wall.

Losses to medfly are negligible when the fruit is harvested just at color break. This is the peak period for internal fruit quality and nutritional value in terms of ascorbic acid content of the juice. Experience of growers in the Carazo area of Nicaragua indicates that picking the whole crop at one time floods the market, however, and grower prices drop to just about half of that expected when fruit is left on the tree and picked over a 4- to 6-week period. If fruit is not picked immediately, the medfly causes an estimated 50 percent loss in value, and in some years, fruit losses may approach 100 percent for growers with a small number of trees.

Mandarin fruit often provides a useful link in the medfly host fruit sequence, as its period of maturation can, in some areas, overlap the November to February coffee maturation period and continue up to May; coffee maturation then resumes in June and July.

Sour orange, B, (*Citrus aurantium* L.)

A limited number of sour orange trees are grown throughout Central America. Isolated trees result from an individual's desire for a source of marmalade; failure of a scion, with the sour orange rootstock taking over; or a seedling erroneously planted for sweet orange.

The sour orange fruit has a moderately thick rind, a loosely knit albedo that is loosely attached to the segments, somewhat tough segment walls, and moderately-packed juice vesicles with tender cell walls. The rind obtains a high degree of varietal color, and the fruit is "puffy" when mature.

When colored, the fruit attracts the fly to oviposition, and larval development is quite good. Losses can be substantial as ovipositing punctures can accentuate premature fruit drop.

Sweet oranges, B, (Citrus sinensis (L.) Osbeck)

Sweet oranges are grown throughout Central America. They are used as shade trees for coffee, planted in small orchards, and seen extensively in dooryard plantings from Guatemala to the tiny thatched homes in villages of southern most Panama.

Losses from fruit fly infestation for sweet oranges and mandarines combined are estimated at 20 percent for Costa Rica (early seedy sweet oranges and early crop navels), 25 percent for Nicaragua (50 percent of the mandarin crop in value and 10 percent of the oranges), and 20 percent for Panama (early seedy sweet oranges and the Boquete navel, which is early).

Early seedy sweet orange selections: These have a tender, somewhat thin rind with good color. They mature during a period of high medfly population density and are thus subject to heavy attack. Few early seedy sweet orange trees were seen in Nicaragua. Costa Rica and the western part of Chiriqui, Panama, had substantial numbers in proportion to their total industry. Citricos de Chiriqui (a 6,000 acre farm) in western Panama has a substantial number of trees resembling the Pineapple selection in Florida are 8 years old and have just now set their first commercial crop - to be harvested in 1972.

Early navel crop: This fruit ripens in February, but in areas of very light textured soil (droughtly soil conditions), they develop excellent color from mid-January to the first of February. They have a thin rind and are moderately well attached at the albedo-segment wall. In the Meseta Central of Costa Rica and at Boquete, Panama, navels maturing in February and March were left on the tree to spread out the harvest season. These suffered extensive fruit drop associated with heavy medfly attack.

Late seedy sweet orange selections and the main navel crop: In general, crop losses to medfly are negligible for these selections. The fruit rind is tough, the albedo generally is closely knit and thick, and rind color development is poor, turning a sickly yellow at full maturity. Even for fruits that color well in the late seedy sweet orange selections, medfly larvae appear to have a difficult time reaching the juice vesicles since

the peel is strongly attached to the segment walls, and the segment walls themselves are tough. The same is true for navel fruit, although the firm albedo is not as strongly attached to the segment wall as in the late seedy sweet and Valencia oranges.

Valencia orange: Valencia orange trees are planted throughout Central America, usually as individual trees or small plantings. Seldom are they seen as shade trees for coffee; citrus used as shade trees for coffee are of seedy sweet orange selections and occasionally navel oranges. Valencia is the major orange planted at Citricos de Chiriqui, Panama, the largest monoculture citrus planting in Central America.

Valencia fruit losses to medfly are negligible. The main crop is picked in July and August during the rainy season, when the medfly population is greatly reduced. Also, the peel is somewhat thick with a tight albedo; the albedo is strongly attached to the outer segment wall; and the segment walls are tough, all conditions quite unfavorable to larvae survival.

Grapefruit, B, (*Citrus paradise* Macf.)

Grapefruit trees are grown throughout Central America, usually in small groups (seldom more than 10 trees) and as scattered trees mixed with other citrus as shade for coffee. Many trees are located in dooryard plantings. The fruits observed had thin rind and a tight albedo, tightly attached to tough outer segment walls. Still, many contained medfly larvae and had extensive internal damage due to larvae feeding. Seldom were more than 6 or 7 larvae found per fruit, however, compared with 35 to 50 sometimes found in mandarins, early seedy sweet oranges, and early crop navel oranges. Often associated with medfly larval feeding was a breakdown (not discolored), presumably due to secondary organisms, in areas surrounding the actual feeding location of the larvae. Extensive fruit drop was associated with the combination of medfly attack and moderate to strong wind. Apparently, medfly attack greatly accelerated and accentuated the formation of the abscission layer.

Grapefruit fruit losses to medfly were estimated at 15 percent in Costa Rica, 25 percent in Nicaragua, and 35 percent in Panama (25 percent due to medfly larval infestation and 10 percent because of abnormal drop due to oviposition).

Shaddock, B, (*Citrus grandis* L.)

Individual or groups of shaddock trees are grown throughout Central America in mixed plantings with other citrus. They are not numerous.

The fruit rind is thick and the albedo is spongy and deep, tightly adhering to the outer segment wall. The segment walls are very tough and the juice vesicle wall structures are firm.

No fruit losses were noted. While oviposition occurred, no subsequent development of larvae past the albedo was observed. The species tends to produce a pronounced fruit abscission layer early, resulting in premature fruit drop. Oviposition was not observed to accentuate fruit drop, however.

Plum, B, (*Prunus* L. spp.; principally, European plum, *P. domestica* L. and the Japanese plum, *P. salicina* Lindl.)

No plum trees were observed; however, they are included because they might possibly be grown in the highland areas.

Back and Pemberton in 1918 reported that excessive moisture of well-ripened plums "drowned" the larvae, particularly those in the juicy Japanese plums. They recommend planting these varieties rather than "dry" varieties. South Africa reports that plums are attacked by medfly only in heavy fruit fly years.

Bodenheimer in 1951 reported Japanese plums to be infested by medfly at the rate of 10 to 20 percent when oviposited at maturity. Those infested while somewhat immature suffered the greatest loss (from 25 to 100 percent).

Tertiary Hosts, C

Mangos, C, (*Mangifera indica* L.)

Perhaps no fruit tree is as well represented throughout Central America as the mango. Most are grown as individual trees or in very small groves.

In medfly-infested areas throughout the world, the mango is considered a favored host. From 6 to 100 percent of the fruits of a tree are infested, depending on the selection. The thick skin selections are least infested,

generally ranging from 6 to 10 percent. Oppenheimer in 1951 in Israel showed that early picking and a selection for the thick skinned varieties offered the best measures for mango growing in medfly-infested areas.

Throughout Central America, it has been the practice to pick mangos early, premature, and while very green to avoid wormy fruit. This practice was because of severe fruit losses to Anastrepha spp., presumably A. mombinpraeoptans Sein in Nicaragua, Costa Rica, and Panama and A. mombinpraeoptans or A. ludens (Loew) or both in Guatemala, El Salvador, and Honduras. In the medfly-invaded areas of Nicaragua, Costa Rica, and Panama, the already established practice of prematurely harvesting mangos because of the tropical American fruit flies removes the fruit well before it color breaks and ripens. Thus, no fruit losses can be attributed to medfly infestation. It is strange, however, that fruit high in the tall trees that ripen and fall to the ground are seldom, if ever, infested by medfly. They are infested, however, by A. mombinpraeoptans.

Red mombin or jocote, C, (Spondias purpurea L. also the yellow mombin, jobo, S. mombin L.)

The same observations noted for mango prevail. The mombins are universally distributed; they are picked and eaten green, and those fruits overripe and fallen to the ground are infested with A. mombinpraeoptans. No fruit losses are attributed to medfly, although the mombins are good to excellent hosts in other medfly-infested areas of the world.

Papaya, C, (Carica papaya L.)

Papaya is cultivated throughout Central America in small solid plantings, as intersets in other crops, and as a dooryard favorite. It is well established in other medfly-infested areas as an excellent host for medfly when it is well colored and overripe. However, no losses due to medfly are noted in Central America because papaya is traditionally picked green or just at the first sign of color break, held 4 or 5 days to ripen, and then eaten. Papaya exude a heavy white sap when punctured until they are well ripened; hence, the fruit is removed before it is a suitable host fruit for medfly. The main loss to papaya is caused by the papaya fruit fly, Toxotrypana curvicauda Gerstaecker, which appears to dominate papaya.

Guava, C, (*Psidium guajava* L. and related species)

Wild and improved forms of guava are scattered throughout Central America. It is used widely to make a refreshing drink.

Guavas are considered a favorite medfly host. In Hawaii, infestation ran to 62 percent of the fruits and in Israel infestations were commonly 70 to 100 percent of the fruits; yet, in Nicaragua, Costa Rica, and Panama, no medfly infestations are found.

When guava fruits are to be used, they are picked slightly green but still quite useable. The reason they are picked green is that, long before medfly infestations in other fruits appeared, the guava was a favorite, if not exclusive, host fruit of *Anastrepha striata* Shiner; guava is dominated by *A. striata*.

Avocado, C, (*Persea americana* Mill.)

One or several of the three recognized ecological races (Mexican, Guatemalan, and West Indian) and their hybrids are grown commercially in Central America. The interest in developing a larger avocado industry is great.

No medfly loss of avocado has been observed or noted in Central America. The fruits are traditionally picked green and hard, allowed to soften, and then eaten. Hence, they are removed from the orchard before they are soft enough to allow successful oviposition. Fruits left on the tree until wrinkled and soft have been lightly infested, principally the thin skinned varieties. Only the fruits of trees of the Guatemalan race (or hybrids with equally thick skins) escape oviposit. Fruits of trees of the Mexican race are thin skinned. The fruits of one, Duke, in Israel, were infested a month before they were mature enough to pick from the tree. Fruits of the West Indian race have leathery tough skins. Leathery tough skins can come from hybrids made from among the races. Skin or peel character cannot be predicted.

Carambola, C, (*Averrhoa carambola* L.)

The carambola is of very limited distribution and appears here and there as a novelty or specimen tree in Central America. Several were observed

growing in a high medfly population density area of Carazo, Nicaragua, and overripe fruits were not infested. However, what appeared to be oviposit scars infected by anthracnose, Colletotrichum sp., were apparent on overripe fruits.

Strawberry, C, (Fragaria virginiana x chiloensis Hedrich)

Strawberries were observed in small, scattered plots throughout the Central American area, mostly for family consumption; however, the Meseta Central, Costa Rica, produces over 2 million pounds per year for export.

Strawberry is rarely a field host for the medfly. Medfly has not been established as a field pest in Hawaii, Florida, Israel, or Greece, but Florida has placed strawberries on the list of fruit subject to attack. Baas reported a 5 percent infestation of "large, ripe fruit" in Frankfort in 1955. These strawberries were growing under heavy medfly-infested apricot and peach trees. Strawberries growing in medfly areas of Carazo and Jinotega, Nicaragua; Meseta Central, Costa Rica; and Boquete, Panama; have not been attacked by the medfly. This is true even though strawberries are often grown between rows of heavily invested citrus trees and in small open plots adjacent to or within coffee fincas of known high medfly density.

Tomato, C, (Lycopersicon esculentum Mill.)

Several tomato varieties are grown extensively in small plots for family consumption or for sale on the local market in limited quantities. Interest is keen to produce early tomatoes for export to the United States.

Although under forced conditions (cage tests) tomato is readily infested, no recent field infestations have been reported (one was reported in Palestine in 1935 and two infested fruits were reported in western Australia in 1955).

No evidence is available to suggest medfly infestation of tomatoes grown in Central America. Many tomato plants are cultivated and fruit well in dooryard plantings and in hedgerows in areas of known high medfly density.

Sweet peppers, C, (*Capsicum annuum* L. var. *grossum* (L.) Sendt.)

Sweet peppers are grown for home use and limited sale. In observing this crop in medfly areas of Central America, most notably the Meseta Central, Costa Rica, we found no medfly infestation even though some fields were adjacent to and between coffee fincas with known medfly infestations. Back and Pemberton, 1918, report fruit infestations up to but not exceeding 5 percent. Bodenheimer, 1951, in Israel, found no field infestation by medfly of sweet green peppers.

Fruit of one of the chillies (near *C. annuum* L. var. *acuminatum* Fingerh.) in the Meseta Central, Costa Rica, was observed to have larvae (personal communication, Dr. R. H. Rhode). This is the only known observation of larvae infestation of chillies.

Cucumber, C, (*Cucumis sativus* L.)

The cucumber is grown locally for the table and for limited marketing. Costa Rica and Guatemala have expressed interest in cucumber-pickle and fresh cucumber exports to the United States.

No medfly infestation of cucumbers has been observed in the Meseta Central, Costa Rica. Cucumber is a suitable host fruit, as are green peppers, in laboratory cage tests. Bodenheimer, 1951, found no field infestation by medfly of cucumbers in Israel.

Cactus fruits, C, (*Opuntia vulgaris*, *O. ficus indica* and other cactus fruits)

One or more of these fruits have been reported infested by Compere in Malaga, Spain, Constantino in Italy, and Back and Pemberton in Hawaii. Bodenheimer in Israel found no infestation of prickly pears. Cactus fruits should be considered, however, as Guatemala commercially grows pitahaya and tuna, and cactus fruits are seen in the market place throughout Central America. No infestation was observed in cactus fruits offered for sale in known medfly areas, however.

Sour lime, D, (Citrus aurantifolia (Christm.) Swing.)

Sour limes (limon) are extensively grown throughout Central America, most commonly in dooryard plantings. Medfly infests only fruit that is injured and partially decayed.

Sweet limes (C. limettioides Tanaka) were not observed in Central America. They are, however, considered susceptible to medfly infestation in other areas of the world.

Sour lemon, D, (Citrus limon (L.) Burm. f.);
rough lemon, D, (C. jambhiri Lush.)

Sour lemon, the lemon of commerce or "California" lemon, is only found as an occasional tree or small group of trees except near San Salvador, where many Bearss and Meyer selections are grown, and at Citricos de Chiriqui, Panama, where there are 900 acres of trees, 6 to 7 years old, of young line Cavers Lisbon, Frost Lisbon, and Frost Eureka. Injured and decaying lemons are sometimes infested by medfly; healthy fruits are not.

Rough lemon is used as a citrus rootstock, and sometimes seedlings are used to provide fresh table fruit. No medfly infestation of rough lemon fruits was seen in Central America, nor is any reported in the literature.

Bananas, D, (Musa spp.)

Where not grown commercially in large monocultures, bananas and the cooking bananas (guineos and plantains) are grown to shade young coffee plants, as intersets in other crops, and cultivated extensively in dooryard plantings.

Bananas picked and prepared for export are never infested by medfly. Eggs oviposited in overripe, decaying fruits occasionally produce an adult fly. Eggs oviposited in very thin skinned cooking bananas, when ripe to overripe, may occasionally support one to several larvae to the pupal stage. Overripe fruits, however, are easily infested in laboratory cage tests.

Grape, D, (Vitis labrusca L. and V. vinifera L.)

Grapevines are grown individually or in small groups. Plantings are widely scattered in Central America and a small wine industry is established in and near Chinandega, Nicaragua.

Grapes are a possible host, but are rarely infested. Infested fruits have not been observed in Central America, although infestations in both species of grapes have been reported in Hawaii, Spain, South Africa, and Israel. Larvae seldom survived to the pupal stage, however.

Passion fruit, D, (sweet granadilla, Passiflora ligularis Juss.; giant granadilla, P. quadrangularis L.)

The sweet granadilla is the selection of passion fruit most frequently found in Central America. The giant granadilla, however, is occasionally cultivated. Medfly has not been found infesting these species.

Only one species of Passiflora is reported to have been infested by medfly. Passiflora caerula L. was reported infested in Hawaii by Back and Pemberton, 1918. They found two fruits out of 600 infested, and these only produced six adult flies. They found no infestation of P. quadrangularis, P. edulis Sims, P. laurifolia L., P. alata, or P. foetida L. Bodenheimer, 1951, reported that P. edulis was not infested by medfly in Israel.

Mammey apple, D, (Mammea americana L.)

The mammey apple is grown as a windbreak for coffee in the Carazo area of Nicaragua, and elsewhere as individual trees and in some hedgerows. One fruit was observed infested by medfly larvae. It was overripe and decaying on the ground. Bodenheimer, 1951, did not find mammey apples infested in Israel. Back and Pemberton, 1918, did not consider mammey apple a host.

Sapodilla, (Manilkara achras (Mill.) Fosberg)

Chicosapote is widely grown for its fruit. It is seldom seen in plantings of more than a few trees. The fruit were observed infested by medfly only when they were very overripe.

Cashew, D, (Anacardium occidentale L.)

The maranon is widely grown as a dooryard tree and as intersets in other crops. It is prized for the cashew apple from which a refreshing drink is made. The cashew apple has not been seen infested by medfly in Central America, nor has it been reported as a host fruit in the literature.

Breadfruit, D, (Artocarpus altilis (Park) Fosberg)

The breadfruit or breadnut tree is grown widely as a dooryard tree, as an ornamental in parkways and parks, as individuals in hedgerows, etc. No infestation has been observed in Central America, but the literature reports medfly infestation of overripe and decaying fruits.

Jackfruit, D, (Artocarpus heterophyllus Lam.)

Observations are the same as for breadfruit above.

Pomegranate, D, (Puncia granatum L.)

A few trees of pomegranate are grown either scattered as dooryard plantings or as specimen trees. Occasionally, medfly infests cracked, overripe fruit.

Naranjilla, D, (Solanum quitoense, Lam.)

Plants were only seen growing at 4,000 to 5,000 feet elevation in the mountains between Matagalpa and Jinotega in Nicaragua, and at 4,500 to 6,000 feet elevation in the mountains near Boquete, Panama. Medfly infestations of the fruit have not been found, nor has any been reported in the literature.

Egg plant, D, (Solanum melongena L.)

Egg plant is occasionally cultivated as a dooryard plant. No infestation of egg plant fruits was observed nor was any reported. One egg plant fruit was found infested in 4 years of careful study in Hawaii by Back and Pemberton, 1918. Bodenheimer, 1951, found no infestation of egg plant fruits in Israel.

Chayote (Sechium edule (Jacq.) Swartz)

Chayote is a good, although recent, export crop for Costa Rica. Chayote is also grown generally in dooryard plantings. It is not a host of medfly as it is picked, packaged, and shipped.

Watermelon, D, (Citrullus lanatus (Thunb.) Mansf.)

Watermelon is widely distributed throughout Central America. It is commercially grown in large and small plots and is a common planting near homes or as dooryard fruit. Watermelon fruit have not been found infested by medfly in the field, but have been infested in laboratory cage tests.

Melon, D, (Cucumis melo L.)

Cantaloupe and the casaba melon are the cultivars most commonly found. El Salvador is trying to establish an export market. These fruits have not been found infested by medfly in the field. They have been infested, however, by medfly in laboratory cage tests.

Pineapples (Ananas comosus (L.) Merr. often called A. sativus) and cocoa pods (Theobroma cacao L.)

These are not hosts for medfly.

CULTURE AND MANAGEMENT METHODS OF FRUIT FLY CONTROL

A clean culture program is one of the oldest methods used to control medfly. Its success depends on complete cooperation of all owners of all host-fruit trees. A vigorous clean culture program apparently eradicated the medfly population in Tasmania in 1899 where a limited medfly population was established in apples, pears, and peaches.

Destruction of fruit, orchard sanitation, and soil treatment with insecticide and/or foliar bait-insecticide sprays have proven useful in the past to gain economic control of medfly, as in the campaigns of New Zealand (1901), Florida (1929), and west Australia (1956).

It is never sufficient to spread the infested, overripe, and decaying fruit over the soil surface expecting the sun to heat up the fruit and thereby overheat and kill the larvae contained within. This practice was observed in Central America. The larvae survive and pupate in the cool, moist soil below the fruit. Similarly, the practice of burying fruit, also observed in Central America, is of little consequence as fruit is seldom covered with sufficient soil and compacted frequently enough to prevent emerging flies from reaching the surface.

In tests, pupae have been buried at various soil depths in different kinds of soil. Adults were found to emerge from under a 40 cm. covering of soil. In western Australia, a claim is made that the flies emerged from 122 cm. soil depth.

When the soil is compacted over infested, ripe, overripe, and decaying fruit, soil cracks, through which flies will emerge, form as a consequence of the buried fruit shrinking in volume as it decomposes.

A continuing program of clean culture requires constant attention by all fruit growers in the area to collect all host fruits, to properly and completely dispose of the fruits (dunking in kerosine filled barrels, burning of all fruits, etc.), and to maintain (prune) host fruit trees to a height where the fruit can be conveniently picked. For maximum efficiency, the clean culture approach should be complemented by foliar insecticide-bait sprays. In areas where spraying is impossible, insecticides should be mixed into the soil beneath the tree skirt.

Management practices can effect control of medfly from essentially two sides; they (1) interrupt the yearly host fruit sequence, and (2) reduce or eliminate the accessibility of host fruits.

The yearly host fruit sequence can be effectively controlled in districts devoted to essentially a monoculture of a host fruit selection(s). All known host fruit trees, shrubs, and trees are rogued, leaving only the commercial crop. Bodenheimer, 1951, reports this type of control measure in Israel where the monoculture is citrus selections.

The reduction or elimination of the accessibility of host fruits is the most widely practiced method of obtaining host fruits free of infestation. Since the medfly is essentially a pest of ripe fruit, the practice for years in those countries having a long history of medfly infestation has been the premature harvesting of their fruit crops. Fruit is removed prior to successful oviposition, resulting in the harvest of green fruit. Both procedures (the removal of noneconomically important host fruit

plants and the premature harvest of fruit) are practiced, since medfly flight distances are long enough to bring medfly to a fruit planting from several kilometers away. Hence, if there is an area of high medfly infestation within a kilometer or two, high medfly population densities can develop in the monoculture. Flies from the outlying areas drift into the monoculture, which was previously rogued of extraneous host fruit plants. They then cause commercially significant losses of the fruit that is left to fully ripen on the tree.

When the yearly trend in medfly population density is known within an area, it is sometimes possible to adjust the harvest period of the host fruit to coincide with medfly population minima. This is done by premature harvest or by planting selected varieties. Only fruit varieties that are known to ripen during the period of low medfly density are planted. The net result is that, in some years, the fruit may escape commercially significant losses.

Another alternative is to plant only crops that have been shown to be free of medfly infestation. The selection of crop is dependent upon the grower's geographical, climatic, and financial situation. Since medfly can attack nearly all the economically important fruits, however, the choice of a medfly-immune fruit crop is, indeed, limited.

POSSIBILITIES FOR CONTROLLING OR REDUCING FRUIT FLY DAMAGE

Varieties

Some general guidelines can be laid down based on observations recorded in the literature.

Apples and pears of firm texture when ripe appear to have less medfly infestation than those of a soft texture. The fruit with a high resistance to puncture, usually the thick skinned fruit selections, withstand attack by medfly much better than those that puncture easily and are thin skinned.

Soft fruits, drupes and berries, generally must rely on a harvest date coinciding with no, or very low, medfly population to render a commercially acceptable crop.

Avocado selections with tough, thick skins will greatly decrease the little economic damage that can be associated with medfly. This probably means planting selections of the Guatemalan race or planting inter-racial hybrids obtained from crosses of the Mexican race or the West Indian race with the Guatemalan race.

Mandarin varieties with thick, tight rind would probably be less susceptible to medfly infestation than the thin, loose rind varieties. These, however, have fruit characters more closely associated with the Valencia orange than with those associated with the thin, loose rind selections now grown in Central America.

The thicker-rind, poorer-quality grapefruit selections would be much less susceptible to medfly attack than the relatively thin-rind, high-quality grapefruit selections now grown.

The "dry" plum varieties are much more susceptible to medfly infestation than are the "juicy," soft varieties. The "juicy," soft varieties, however, do not ship well. This is an important consideration, judging from the road conditions in most agricultural areas of Central America.

Mango varieties can be selected for thickness of skin. The thick skinned varieties in Hawaii and Israel were much less infested by medfly than were the thin skin selections. The primary pest of mangos in the medfly infested areas of Central America, however, is Anastrepha mombinpraeoptans, and nothing is known about the effect of peel thickness on A. mombinpraeoptans infestations.

Changes in Horticultural Production Practices

Medfly infestations are of serious economic importance in Central America only in the production of citrus crops. Citrus is the only commercial primary or secondary host fruit crop, other than coffee, widely grown on an economic scale. Medfly infestation has no significant effect on the production of coffee beans. Medfly larvae attack the fleshy mesocarp and then only after the coffee bean is well developed. Larvae do not invade the endocarp (parchment) or the bean. Mango, mombins, and guavas are dominated by Anastepha spp., and the papaya and avocado are harvested before they are susceptible to successful medfly oviposition. No infestations of strawberry were observed or found reported in Central America for tomatoes, sweet peppers, cucumbers, melons, squashes, egg plant, chayote, etc. Possibilities for reducing medfly damage through changes in horticultural practices, therefore, focus on the production of citrus fruits.

To predict horticultural practices that might reduce medfly damage, the nature of medfly attack on citrus fruit must be considered. The relative numbers of fruits containing larvae in the pulp vary with variety and season. Fruits of citrus selections that have thin, loose peel and

mature in the dry season from mid-January to May, the period of high medfly population density, suffer the most medfly attack. Fruits of citrus selections with a thick, firm peel that is strongly attached to outer segment walls and mature in the wet season from mid-June to October, the period of low medfly population density, are the least infested by medfly. Major peel characteristics and the maturation period of fruits are governed by variety. Season to season variations in medfly attack, however, are dependent on the vagaries of climate, weather, and host fruit sequence (host suitability and quantity of host fruits available in a continuous seasonal sequence).

When citrus fruits are still green or just color breaking, oviposit punctures generally contain eggs which fail to develop, and the mortality of young larvae that are produced is very high. Normally, the female makes an oviposition cavity between the flavedo and in the albedo (between the albedo and outer segment wall in fruits with very thin peel) and lays her eggs either in the bottom of the cavity or on its walls. Essential oils released (oil cells located in the flavedo) on oviposition inhibit egg development. Moreover, there is a physiological host reaction to the oviposit puncture and cavity. Cells around the oviposition cavity are thickened (scleritized) and lignin and gums are secreted into the egg cavity and/or accumulate in surrounding cells. This severely limits the ability of the larvae that develop to reach the juice vesicles. Hence, the number of eggs that develop normally, and those that give rise to larvae that reach the pupal stage is relatively small. Larvae that survive seldom penetrate into the segments. The physical texture of the peel is generally compact at this stage of fruit development.

Medflies are attracted to oviposition when the fruit is ripe and has good varietal color. The relative number of eggs that develop normally and the relative number of larvae that survive to penetrate into the segments is low, but the number of eggs oviposited in a fruit can be rather high. Several females will oviposit in the same cavity.

The physical texture, resistance to puncture (a measure of rind firmness), and the chemical composition of the peel change during the maturation process. The rind softens and physiologically the cells lose much of the juvenile ability to form thickened cell walls and deposit lignin and gums. The cells of the albedo, while compact and firm in the juvenile fruit development stage, become more loosely arranged as the fruit matures.

The resistance to successful oviposition, to subsequent development of eggs, and to the survival of larvae diminishes and fruit attraction to oviposition increases as the fruit matures. Treatments, therefore, that would retard rind coloring, thicken the rind, or aid in the retention of the juvenile rind characteristics are most likely to reduce medfly damage.

Fruit on trees in physiological stress color prematurely. Early depletion of soil moisture without rain or supplemental irrigation, incipient nitrogen deficiency, or both, enhance "June" drop, and for these fruits maturing during the dry season, greatly accelerate development of varietal rind color. Hence, careful attention to maintaining adequate soil moisture and the mineral nutrition of the tree would aid in the delay, if not the reduction, of medfly damage by preventing premature rind coloring and softening and the concurrent attraction of medfly to oviposition.

Peel thickness can be influenced by mineral nutrition. Fertilizer applications that develop a high level of foliar nitrogen and potassium concentrations can significantly increase the thickness of the rind, particularly the albedo, and influence the toughness of the rag (principally the segment walls). High levels of nitrogen and potassium also delay the onset of varietal color and decrease the intensity of the varietal color developed. Thus, the successful transition of egg to pupal stage is discouraged and the attraction to oviposition delayed.

The toughening of citrus rind was thought to be one side effect produced by lime sulfur applications. In experiments in California, however, it was found that lime sulfur applications of 29 percent calcium polysulfide, 1.9 lb./gal., and calcium and sulfur as gypsum, 3 lb./gal., had no significant effect on rind resistance to puncture (personal communication, H. Z. Hield). Even at rates of application up to three times the concentrations noted gave no significant change in rind resistance to puncture (personal communication, G. L. Henning).

During fruit maturation, rind pigment changes, tissue softens, carbohydrates increase, and carbohydrate metabolism and cation concentrations (notably an increase in the K/(Ca + Mg) ratio) change. The development of varietal rind color, greatly reduced resistance to rind puncture, increased susceptibility to decay, and the increased incidence of "puffy" rinds are features of ripe fruit that are conducive to medfly investation. All these factors can be significantly delayed, retarded, or reduced in magnitude by the use of gibberellic acid (GA_3) without significantly influencing internal fruit quality factors. The primary effect of GA_3 foliar sprays is on prolonging the juvenile character of the rind.

It is questionable that the use of GA_3 on fruit varieties with thin, loose rind (mandarins) or on fruit varieties with "puffy" rind (sour oranges) to reduce medfly damage would overcome these varietal characteristics. Gibberellic acid, however, could afford some help in reducing medfly damage of these fruit through delayed rind coloring and the maintenance of a high degree of rind resistance to puncture.

Changes in Crop Pattern

There are few realistic changes in crop pattern that can be suggested. Crop patterns are well established. There is not enough net monetary return to justify the removal and replanting of crops in an effort to breakup the seasonal sequence of host fruits. Coffee is the main economic fruit crop and one of the main host fruit carryover crops. Hence, the removal of such a crop, which in itself is not significantly damaged by medfly, to reduce medfly damage in fruit crops of much less total monetary value is out of the question. Since citrus, the second most economically important host crop, is primarily grown in mixed plantings, particularly in coffee fincas where it provides both shade and fruit, no substitute can be advised that could function in the same manner, return nearly as much dollar value, supply the nutritional needs of the people, and be free of medfly damage itself.

MEASURES AND ESTIMATED COSTS OF ERADICATION OR CONTROL OF THE MEDFLY

MEASURES REQUIRED

Quarantine

A strict quarantine enforcement is essential to supporting an effective eradication or suppression program. This requires quarantine operations such as baggage inspection and elimination of insects from within and outside infested areas for land, aerial, and maritime transport arriving at international boundaries. Human and commercial movement of products and transport vehicles are considered principal means of spread of the medfly, and a quarantine program is necessary to prevent the fly from being carried into areas where it is not now established.

If an attempt is made to eradicate the fly in Costa Rica, Nicaragua, and Panama, a quarantine program would be necessary to detect movement of any infested fruits or contaminated vehicles, whether from outside Central America or from locations within the area where eradication is not yet complete.

Quarantine efforts against reinfestation should be concentrated on shipments, travelers, and vehicles arriving from South America, Europe, and other countries where the medfly is present.

If the medfly is not eradicated in Central America, a quarantine program will still be necessary to retard its movement into new areas. An effective quarantine program along the highways in northern Nicaragua is urgently needed to retard the spread of the medfly into Honduras. Established infestations in Nicaragua are known as far north as Corinto-Chinandega on the coast and at Jinotega in the high coffee country east of the Pan-American Highway. Because the highway between Choluteca, Honduras, and Somotillo, Nicaragua, will be completed in 1972, a new road station north of Chinandega needs to become operational to check the traffic moving into Honduras along this road.

Inspection will also be required for the air traffic (primarily cotton crop dusters) plus the railroad traffic and the maritime traffic at nearby Corinto. Teams working out of the Chinandega station could handle these assignments.

With a road station on the Pan-American Highway at Condega or Esteli, a check could be made of the traffic moving westward through Somoto or northward through Ocotal to El Paraiso, the next important projected highway into central Honduras.

Table 3 shows estimates of costs to make the two new quarantine road stations functional, to supervise them and to check international road traffic moving into Honduras at El Triunfo, El Espino, and Los Manos. Figures for augmenting the crews and quarantine facilities now in use by the Honduran government are not included. Shortwave radio communications are essential for all operations, and it is assumed such facilities exist at the ports of entry.

Survey (Trapping) Program

A prerequisite for consideration of any kind of program or activity to control or eradicate the medfly is a thorough, systematic, and continuous survey (trapping) program throughout Central America to positively determine its distribution, exact locations, and relative populations. Estimates of personnel, equipment, facilities, and costs for a survey program for the six Central American countries are shown in Table 4.

Figures in parenthesis are items and personnel which country governments would contribute by reassigning personnel, office space, equipment. etc., presently engaged in similar activities. The total costs shown in Table 4 include these items, while the net costs do not. Thus, the net costs indicate new financing from other domestic or external sources which would be necessary for such a program.

A number of zones for each country were arbitrarily set up based on the area a supervisor could effectively handle. It was estimated that one man could effectively operate 300-350 traps. Materials for trapping are based on current prices, mostly f.o.b. factory. Vehicle cost estimates are based on GSA lease and maintenance costs.

Surveys should be operational a full year before an area eradication program is initiated and then continue indefinitely after treatment to detect persistent or new infestations.

Although these survey cost estimates were developed specifically for the medfly, similar survey work could be done for other insects with very little additional cost, using the same personnel, equipment, and administrative structure. This survey work should be an integral and

Table 3. Estimated costs of operation and area supervision of the quarantine stations in northern Nicaragua and the international ports of entry into Honduras.

Item	Cost 1 yr.	Cost 4 yr.
	U. S. dollars	
Area supervision		
Survey staff of country with American counterpart as advisor	---	---
1 supervisor (both stations and international ports of entry) 600/mo.	7,200	28,800
Per diem for supervisor	2,000	8,000
Vehicle for supervisor	2,400	9,600
1 shortwave radio for car	600	600
TOTAL	12,200	47,000
Operation of quarantine station between Candega and Esteli, Nicaragua		
1 foreman 400/mo.	4,800	19,200
6 inspectors 150/mo.	10,800	43,200
2 vehicles 200/mo.	2,400	9,600
1 gas chamber	2,000	2,000
EDB gas 2 gal./mo. @ $8/gal.	192	768
Roadhouse, electricity and/or butane	2,000	8,000
2 generating plants (1 as a reserve)	4,600	4,600
2 shortwave radios	1,200	1,200
Miscellaneous costs	1,000	4,000
TOTAL	28,992	92,568
Operation of quarantine station North of Chinandega, Nicaragua		
1 foreman 400/mo.	4,800	19,200
1 sub-foreman 250/mo.	3,000	12,000
9 inspectors 150/mo.	16,200	64,800
4 vehicles 200/mo.	9,600	38,400
1 gas chamber	2,000	2,000
EDB gas 3 gal./mo. @ $8/gal.	288	1,152
Roadhouse, electricity and/or butane	2,000	8,000
2 generating plants (1 as a reserve)	4,600	4,600
2 shortwave radios	1,200	1,200
Miscellaneous costs	1,200	4,800
TOTAL	44,888	156,152
GRAND TOTAL	86,080	295,720

Table 4. Estimated costs for medfly surveys in Central America: Regional (international) offices for Central America and national headquarters for El Salvador at San Salvador, El Salvador.

Item	Cost 1 yr.	Cost 4 yr.
	U. S. dollars	
International and national El Salvador headquarters		
1 supervisor (American)	22,000	88,000
1 supervisor (national)	(9,000)	(36,000)
1 assistant supervisor (national)	(7,200)	(28,800)
Air travel & per diem for the supervisors	5,000	20,000
2 autos, (4-wh.-drive station wagons) @ $200/mo.	2,400	9,600
2 clerk-stenographers	6,000	24,000
2 typewriters	900	900
2 calculators	700	700
1 duplicator	250	250
Misc. office supplies	1,500	6,000
Office and/or furniture rental	(2,400)	(9,600)
Total international headquarters	57,350	223,850
Less: national contribution	-18,600	-74,400
Net cost, external	38,750	149,450
Survey zones (El Salvador)		
2 foremen for 2 zones 400/mo.	9,600	38,400
8 trappers 200/mo.	19,200	76,800
Per diem for trappers	1,200	4,800
5 vehicles @ 200/mo.	12,000	48,000
Animal hire, 2 ea., 50 wk. at $10/wk.	1,000	4,000
Office space, furniture, car lot	(1,000)	(4,000)
2,700 sticky board traps/yr @ 0.15	405	1,620
54,000 inserts for traps/yr @ 0.01	540	2,160
Trimedlure, 67.5 lb./yr. @ $15.00 lb.	1,013	4,052
Tack-trap, 607.5 lbs./yr. @ 0.50 lb.	304	1,216
Trap cleaning, pack equipping, etc.	1,200	4,800
Total El Salvador	47,462	189,848
Less: national contribution	-1,000	-4,000
Net cost, external	46,462	185,848
Grand total, El Salvador	104,812	413,698
Less: national contribution	-19,600	-78,400
Grand net, external	85,212	335,298

Table 4. (continued) Estimated costs for medfly surveys in Central America: Nicaragua

Item	Cost	
	1 yr.	4 yr.
	U. S. dollars	
National headquarters		
1 survey supervisor (American)	20,000	80,000
1 survey supervisor (national)	(9,000)	(36,000)
Air travel and per diem for both	5,000	20,000
2 autos, (4-wh. drive station wagons) @ $200/mo.	2,400	9,600
1 clerk-stenographer	3,000	12,000
1 typewriter	450	150
1 calculator	350	350
1 duplicator	250	250
Misc. office supplies	1,000	4,000
Office and/or furniture rental	(1,200)	(4,800)
Total Nicaragua	42,650	167,150
Less: national contribution	-10,200	-40,800
Net cost, external	32,450	126,650
Survey zones		
3 foremen for 3 zones $400/mo.	14,400	57,600
18 trappers $150/mo.	32,400	129,600
Per diem for trappers	3,600	14,400
12 vehicles @ $200/mo.	28,800	115,200
Office space, furniture, car lot	3,600	14,400
6,000 sticky board traps/yr. @ 0.15	900	3,600
120,000 inserts for traps/yr. @ 0.01	1,200	4,800
Trimedlure, 150 lbs./yr. @ $15 lb.	2,250	9,000
Tack trap, 1350 lbs./yr. @ 0.50 lb.	675	2,600
Misc. trapping and cleaning supplies, etc.	3,000	12,000
Total Nicaragua (external)	90,825	363,200
Grand total, Nicaragua	133,475	530,650
Less: national contribution	-10,200	-40,800
Grand net, external	123,275	189,850

Table 4. (continued) Estimated costs for medfly surveys in Central America: Honduras and Guatemala

Item	Cost 1 yr.	Cost 4 yr.
	------U. S. dollars------	
National headquarters		
1 survey supervisor (American)	20,000	80,000
1 survey supervisor (national)	(9,000)	(36,000)
Air travel and per diem for both	4,000	16,000
2 autos, (4-wh. drive station wagons) @ $200/mo.	2,400	9,600
1 clerk-stenographer	3,000	12,000
1 typewriter	450	450
1 calculator	350	350
1 duplicator	250	250
Misc. office supplies	1,000	4,000
Office and/or furniture rental	(1,200)	(4,800)
Total, each country	41,650	163,450
Less: national contribution	-10,200	-40,800
Net cost, external	31,450	122,650
Survey zones		
3 foremen for 3 zones $400/mo.	14,400	57,600
18 trappers $150/mo.	32,400	129,600
Per diem for trappers	4,800	19,200
9 vehicles @ $200/mo.	21,600	86,400
Animal hire, 6 ea., 50 wks. @ $10/wk.	3,000	12,000
Office space, furniture, car lot	3,000	12,000
6,000 sticky board traps/yr. @ 0.15	900	3,600
120,000 inserts for traps/yr. @ 0.01	1,200	4,800
Trimedlure, 150 lbs./yr. @ $15 lb.	2,250	9,000
Tack trap, 1,350 lbs./yr. @ 0.50 lb.	675	2,700
Trap cleaning, pack equipping, etc.	3,000	12,000
Total, external	87,225	348,900
Grand total, each country	128,875	512,350
Less: national contribution, each country	-10,200	-40,800
Net cost, external, each country	118,675	471,550
Grand net, external for both Honduras and Guatemala	237,350	943,100

Table 4. (continued) Estimated costs for medfly surveys in Central America: Costa Rica

Item	Cost	
	1 yr.	4 yr.
	U. S. dollars	
National headquarters		
1 survey supervisor (American)	20,000	80,000
1 survey supervisor (national)	(9,000)	(36,000)
Air travel and per diem for both	4,000	16,000
2 autos, (4-wh. drive station wagons) @ $200/mo.	2,400	9,600
1 clerk-stenographer	3,000	12,000
1 typewriter	450	450
1 calculator	350	350
1 duplicator	250	250
Misc. office supplies	1,000	4,000
Office and/or furniture rental	(1,200)	(4,800)
Total: Costa Rica	41,650	163,450
Less: national contribution	-10,200	-40,800
Net cost, external	31,450	122,650
Survey zones		
2 foremen for 2 zones $500/mo.	12,000	48,000
8 trappers $200/mo.	19,200	76,800
Per diem for trappers	3,000	12,000
6 vehicles @ $200/mo.	14,400	57,600
Animal hire 4 ea., 50 wks. @ $10/wk.	2,000	8,000
Office space, furniture, car lot	2,400	9,600
2,700 sticky board traps/yr. @ 0.15 ea.	405	1,620
54,000 inserts for traps/yr. @ 0.01 ea.	540	2,160
Trimedlure, 67.5 lbs./yr. @ $15 lb.	1,013	4,052
Tack tray, 607.5 lbs./yr. @ 0.50 lb.	304	1,216
Trap cleaning, pack equipping, etc.	1,200	4,800
Total, external	56,462	225,848
Grand total, Costa Rica	98,112	389,298
Less: national contribution	-10,200	-40,800
Grand net, external	87,912	348,498

Table 4. (continued) Estimated costs for medfly surveys in Central America: Panama, and totals

Item	Cost 1 yr.	Cost 4 yr.
	U. S. dollars	
National headquarters		
1 survey supervisor (American)	20,000	80,000
1 survey supervisor (national)	(9,000)	(36,000)
Air travel and per diem for both	4,000	16,000
2 autos, (4-wh. drive station wagons) @ $200/mo.	2,400	9,600
1 clerk-stenographer	3,000	12,000
1 typewriter	450	450
1 calculator	350	350
1 duplicator	250	250
Misc. office supplies	1,000	4,000
Office and/or furniture rental	(1,200)	(4,800)
Total: Panama	41,650	163,450
Less: national contribution	-10,200	-40,800
Net cost, external	31,450	122,650
Survey zones		
2 foremen for 2 zones $500/mo.	12,000	48,000
8 trappers $200/mo.	19,200	76,800
Per diem for trappers	2,400	9,600
5 vehicles @ $200/mo.	12,000	48,000
Animal hire 4 ea., 50 wks. @ $10/wk.	2,000	8,000
Office space, furniture, car lot	(1,000)	(4,000)
2,700 sticky board traps/yr. @ 0.15 ea.	405	1,620
54,000 inserts for traps/yr. @ 0.01 ea.	540	2,160
Trimedlure, 67.5 lb./yr. @ $15 lb.	1,013	4,052
Tack trap, 607.5 lb./yr. @ 0.50 lb.	304	1,216
Trap cleaning, pack equipping, etc.	1,200	4,800
Total: Panama	52,062	208,248
Less: national contribution	-1,000	-4,000
Net cost, external	51,062	204,248
Grand total, Panama	93,712	371,698
Less: national contribution	-11,200	-44,800
Grand net, external	82,512	326,898
Grand total, Central America	687,861	2,730,044
Less: national contribution	-71,600	-286,400
Grand net, external financing	616,261	2,443,644

Figures in parentheses () assumed to be contributed by reassignment of personnel and facilities now engaged in similar work by host country.

permanent part of the Ministry of Agriculture in each country, and not a special activity or program charged only to the medfly.

The trapping or survey activities already being conducted would be absorbed by the program suggested here. Emphasis is given to a survey program because of the essential nature of this activity throughout all of the Central American countries, not only for control of the medfly, but also for other insect pests.

Scheduling of an Eradication Program

The goal of an eradication program would be to suppress and eventually eradicate the medfly in Central America. Eradication could conceivably be achieved by use of insecticide-bait sprays, sterile fly releases, or a combination of both.

Practically, repeated widespread spray application of insecticide as ultra low volume (ULV) would suppress many insects other than the medfly in the eradication area. Some insects, such as honey bees and certain parasitic and predatory insects, are beneficial and their suppression would not be desirable, however. The use of insecticide plus bait would not require complete coverage of every acre of surface, and the bait is primarily selective for fruit flies, so the impact of bait spray on other insects would not be as great as from 100 percent coverage with a technical insecticide.

Application of insecticide-bait sprays by air is more costly than the technical insecticide as ULV due to the much larger volume of spray material that must be dispersed in larger droplet size, which reduces considerably the width of swath which can be covered.

For areas which are too rough or mountainous for spray application by airplanes, insecticides would have to be applied by ground equipment in any event. For this, the bait spray would be more appropriate since it can be applied in spots and 100 percent coverage is not necessary. Malathion plus the attractant bait would be more acceptable because of the longer residual effect which would reduce the cost of maintaining insecticide coverage.

Sterile fly releases are specific in their effect; sterile medflies affect only their own species. For relatively level areas--essentially the same areas which would be sprayed with insecticide by air--sterile flies can be released from airplanes. It would not be feasible to release sterile flies in mountainous areas by air.

Consequently, a sterile medfly release program would necessarily be a combination of methods: release of sterile flies over areas suitable for dissemination by aircraft; bait sprays applied by ground facilities in areas not accessible or suitable for aircraft application; and when necessary to substitute for sterile fly release, spray cities and towns by air using technical malathion as ULV, which would be the least harmful to car paint.

Because of the necessity for clear weather for aircraft flights and absence of rainfall for effective application and impact of insecticides, spraying activities have to be during the dry period. This would mean beginning spray operations in October or November, when the dry season in most areas in Central America begins. This is also the period of low medfly population, so that a spray program initiated at this time and continued for 8 weeks (which would cover at least two and possibly three generations of flies) should be most effective in reducing the fly population, preventing its buildup in coffee, and severely limiting any spread. Thus, the first year program should reduce the medfly population to a very low level, with complete eradication in most of the area treated. This would also immediately eliminate medfly crop damage.

The effectiveness of sterile flies is not adversely affected by rainfall, as are insecticide sprays, so releases during the rainy season are feasible. For effective fly population suppression to near zero levels, continuous releases for at least 4 months may be necessary.

It would appear advisable to start sterile releases sometime between June and September after rains and/or lack of host fruits have reduced medfly populations to a minimum, which would be indicated by trap readings. Two releases would be made weekly at the rate of 100,000 flies/sq. km. per week. This practice may take as much as 6 months or more before eradication of native flies is realized. In the interim, if localized buildup of flies is detected, this locality can be sprayed twice with ULV malathion, 1 week apart, and after an interval of another week, sterile fly releases could be resumed.

An alternate schedule could be to start sterile releases as late as September, and if eradication or a high degree of suppression is not

achieved by December, the trouble spots could be treated by aerial spraying to reduce the native population to a workable level, and then resume sterile release.

Optimistically, successful eradication could be realized in 1 year by either of these schedules. Surveillance by a systematic trapping program would have to continue indefinitely, however, to detect any residual native infestation and/or reinfestation.

It is not possible to accurately estimate the effectiveness of such an eradication program in advance. However, it seems reasonable to believe that, after one season with an eradication program such as outlined, only scattered pockets of native fly population would persist. Thus, the second and subsequent years' activities would consist principally of trapping to detect remaining medfly-infested pockets and to localize eradication efforts.

Because of the massive scope of a program to eradicate the medfly in Central America, it is reasonable to think in terms of a 3- to 5-year eradication program followed by a trapping program and local "mop-up" activities. In addition to reducing the investment in facilities and equipment, particularly for a sterile fly release program, a multistage program concentrating on a part of the entire area each year would permit more efficient utilization of resources and personnel, better supervision and training, and more time for accumulation of experience and information regarding the medfly. This is especially important since there are many unknowns concerning the medfly in Central America and specific measures which would be required for effective eradication. Experience and information gained in one area the first year could be used to carry out more effective eradication at a lower cost in other areas in the second and subsequent years.

In considering possible medfly eradication programs, it was assumed that the large scale, blanket use of insecticides toxic to animal life or with a long residual effect would not be acceptable. Consequently, in the suggested eradication programs, malathion was considered the basic insecticide for both aerial and ground application. Malathion is effective against the medfly, is benign to warm-blooded animals and birds, and has a residual effect of less than 1 week. Also, malathion is readily available in large quantities and is relatively inexpensive.

Although an insecticide with longer residual effect would reduce the cost of maintaining coverage, presently there is none available which is approved for widespread application.

Eradication Program Monitoring

It is essential that any medfly eradication program be accompanied by an intensive monitoring program which would provide accurate, current information on the distribution and concentration of native (and of released sterile) flies throughout the treatment area. This monitoring program would be in addition to the continuing survey program, and would pinpoint those areas needing continued treatment and those where the native population is eradicated. An intensive monitoring program is in itself relatively expensive, but prompt readings of the effectiveness of the eradication program would permit reduction in the number or area of treatments or releases as adequate ratios of sterile to native flies are achieved, and as there is evidence that native fly populations have been eradicated. It is estimated that monitoring a sterile release area of 1,000 $km.^2$ for a year (50 weeks) would cost about $700,000 (Table 5).

Consequently, although the monitoring program is shown as an additional cost, it is likely that total costs of an actual eradication program would be reduced by the information provided by the monitor program. It is impossible to predict in advance exactly how much costs would be reduced, however, so the estimated total costs, unreduced, are shown. When eradication has been achieved, treatment and the monitoring program could be terminated. The less-intensive but permanent survey trapping program would then provide the means for detecting any new infestation which could be treated by a spray and/or a sterile release program covering the locality affected. Intensive monitoring should also accompany localized mop-up campaigns such as these to guide the times and areas of application of insecticide and/or sterile flies and indicate when eradication of native flies has been achieved.

Applied and Supporting Research

For an eradication program of the size and scope projected for Central America, other methods of insect pest annihilation must be developed or improved. In fact, a program of these proportions would be subject to criticism if supporting research were not undertaken. The objective would be not only to advance our knowledge in new techniques, but also to meet emergencies as will inevitably develop, such as temporary shortages of supplies (insecticides, protein bait, rearing materials, etc.), diseased fly colonies, or a prolonged period of inclement weather.

Research in Hawaii has demonstrated new methods for male eradication of the medfly which show considerable potential. These techniques use

Table 5. Estimated costs of monitoring a hypothetical 1,000 sq. km. medfly eradication project by sterile fly releases (servicing and examining 10,000 traps weekly for 50 weeks)

Item	Cost per year per 1,000 km.^{2}
	U. S. dollars
Established salaried supervisory-clerical staff of host country	--*
2 typists @250/mo.	6,000
Office equipment (typewriters, files, etc.)	9,000
1 technician @350/mo.	4,200
3 laboratory technicians @250/mo.	9,000
30 laboratory helpers @125/mo.	45,000
12 foremen @250/mo.	36,000
6 mechanics @250/mo.	18,000
130 trappers @125/mo.	195,000
130 vehicles @200/mo.	312,000
3 warehouses with yards, etc.	36,000
120,000 sticky board traps @$0.15	18,000
500,000 inserts for traps @$0.01	5,000
12,000 hangers for traps @$86/1,000	1,032
Trimedlure, 300 lbs. @$15.00	4,500
Tack trap 6,000 lbs. @$0.50	3,000
TOTAL	701,732

*General supervision provided by permanent national survey staff.

9" strings or 1/4"-1/2" cane fiber squares impregnated with trimedlure and naled (dibrom), spread by ground or air. Initial studies could be planned for small villages inaccessible by motor vehicle, areas too rugged for frequent aerial fly releases or chemical applications, or valleys with such frequent rainfall that hand spraying is impractical. Need for further large scale study of these and other new potential techniques is justified because the impregnated medium remains effective 3-4 weeks irrespective of weather conditions.

Also, we would be amiss, at the inception of such a control program, if we did not investigate the biology, life habits, and new control methods of this fly in its Central American environment. Knowledge thus gained could be used advantageously for other tropical fruit flies also found infesting a wide variety of medfly host fruits other than coffee, such as mango, mandarin and other citrus, papaya, peaches, and guava. It is necessary to harvest most of the crops when preripe to avoid infestation of fruits by existing fly fauna. This is a major economic loss to these countries, as demand for the fruit is lower and fruit flavor and nutrient value is substandard. Furthermore, control of these flies would result in a larger supply of fresh fruits for consumption in Central America, which would contribute to an improved diet.

In field sampling, we need to determine the number of traps required or fruit samples to be taken to give reliable data. This would enable a more economical execution of a successful eradication project and give dependable measure of the followup monitoring of surveys required over a long term during the post-eradication period.

Also of potential value is the study of the use of remote sensing to determine areas planted to coffee. If this technique proved practical, it would have immediate use for locating coffee plantings, particularly in northern Nicaragua and southern Honduras.

Aside from the survey investigation, costs of these research projects could be underwritten by the overall eradication program, taking advantage of laboratory facilities and staff at the fly-rearing headquarters and substations.

ESTIMATED COSTS OF ERADICATING THE MEDFLY IN CENTRAL AMERICA

For evaluation and comparison of the relative costs of different methods of eradicating the medfly, cost estimates were developed for 3 methods of eradication: technical insecticide as ULV, insecticide-bait, and sterile

fly release. First, estimates are developed for the direct costs of eradication, and the areas involved. Later costs for a comprehensive practical program, including indirect and overhead costs, using the three methods, are developed and compared.

Cost of Application of Technical Insecticide and Insecticide-bait

The medfly is present in Panama, Costa Rica, and Nicaragua. Figure 1, page 9, shows the areas of infestations, and Table 6 gives the size of each area and the approximate percentages that can be treated by aircraft and ground equipment. The total area is 10,774 square kilometers (acreage determinations were made by multiplying square kilometers by 247.1).

It was the judgement of the medfly team, in consultation with others acquainted with the infested areas, that, in all but three of the air-treated areas, about 25 percent of the area could not be treated adequately by air and would require ground applications of insecticide. The Matagalpa-Jinotega (Nicaragua) area was considered too rough for air application and ground treatment would be needed for all of the area. Only 40 percent of the Puntarenas-San Marcos and Potrero Grande areas in Costa Rica, and 60 percent of the Rio Chiriqui-Viejo Boquete-David area in Panama, was considered safe for air application of chemicals or sterile flies. Areas which would require treatment by ground spraying facilities comprise a total of 3,740 kilometers; 7,034 km^2 could be treated by air.

Table 7 lists the inputs and costs of applying ULV malathion in 800-foot swaths on 1,738,100 acres (7,034 square kilometers), and also the costs for treating the same acreage applying technical malathion-PIB-7 in 400-foot swaths. C-123 multiengine jet-assisted aircraft flying at elevations between 150 and 200 feet would be employed in this work. ULV malathion alone has not yet been proven completely effective against the medfly, but it is felt that, due to its low cost compared to malathion plus protein bait, it should be given every opportunity to prove itself. While not 100 percent effective in complete eradication, it is known to be very effective for a quick knockdown of flies.

Table 7 also shows the inputs and cost of using malathion-PIB-7 bait spray in place of ULV malathion spray. Here, due to the heavier and larger spray droplets in the bait spray, only 400-foot swaths can be treated effectively. Thus, the increased cost of bait spray application brings total costs for treating the 1,738,100 acres to about $6.8 million,

Table 6. Areas supporting a self-sustaining population of Mediterranean fruit fly, *Ceratitis capitata* (Wied), the approximate percentage and size of each area that can be treated from aircraft and that which must be treated from the ground.

Country and locality	Area of surface		Treatment area			
	km.^{2}	Acres	Air		Ground	
			Percent	km.^{2}	Percent	km.^{2}
COSTA RICA						
Tilaran-Arenal	252	62,270	75	189	25	63
Villa Quesada-La Fortuna	864	213,494	75	648	25	216
Meseta-Central	2,880	711,648	75	2,160	25	720
Puntarenas-San Marcos	1,376	340,010	40	550	60	826
San Isidro de General	240	59,304	75	180	25	60
Buenos Aires	280	69,188	75	210	25	70
Potrero Grande	198	48,926	40	79	60	119
San Vito	280	69,188	75	210	25	70
Manzanillo-Puerto Cortes	630	155,673	75	473	25	157
TOTAL[a/]	7,000	1,729,700	XX	4,699	XX	2,301
NICARAGUA						
Matagalpa-Jinotega	297	73,389	0	0	100	297
Camoapa	28.5	7,042	75	22	25	7
Santa Tomas-Santo Domingo-La Libertad	540	133,434	75	405	25	135
Masaya-Carazo	806	199,163	75	605	25	201
TOTAL[a/]	1,671.5	413,027	XX	1,032	XXX	640
PANAMA						
Rio Chiriqui-Viejo-Boquete-David	1,824	450,710	60	1,094	40	730
Gualaca-Horconcitos	278.4	68,793	75	209	25	69
TOTAL[a/]	2,102.4	519,503	XX	1,303	XX	799
GRAND TOTAL	10,774	2,662,231		7,034		3,740

a/ Some of individual items may not add to totals due to rounding.

Table 7. Estimated cost to spray 1,738,100 acres of medfly-infested areas by air using ULV Malathion, in 800-foot swaths, and Malathion-PIB-7 concentrate, in 400-foot swaths, 1 and 8 applications

	Per acre		Total--1,738,100 acres	
	1 appl.	8 appl.	1 appl.	8 appl.
ULV malathion	U.S. dollars			
Aircraft (contract)[1/]	0.16	1.28	278,096	2,224,768
Malathion 2 oz./acre @ 0.04/oz.	.08	.64	139,048	1,112,384
Supervision and hand labor[2/]	.003	.024	5,214	41,714
TOTAL	.243	1.944	422,358	3,378,866
Malathion and PIB-7				
Aircraft (contract)[1/]	.32	2.56	556,192	4,449,536
Malathion 2 oz./acre @ 0.04/oz. & 8 oz. PIB-7 @ 0.01	.16	1.28	278,096	2,224,768
Supervision and hand labor[3/]	.006	.048	10,429	83,429
TOTAL	.486	3.888	844,717	6,757,733

1/ Data supplied by Chris Stoltzfus Company, Coatesville, Pennsylvania. Based on use of C-123 aircraft.

	Per Hour	Per Acre
2/ 1 U.S. supervisor $20,000/yr. ÷ 1760 hrs. (220 days X 8 hrs.) =	$ 11.36	
1 Local supervisor $800/mo. = $9,600/yr. ÷ 1880 hrs. (235 days x 8 hrs.) =	5.11	
4 Laborers $150/mo. = $1,800/yr. ÷ 1960 hrs. (245 days x 8 hrs.) = $0.92/hr. x 4 =	3.68	
TOTAL	$ 20.15	
$20.15 ÷ 6400 acres/hr. (16,000 acres ÷ 2 1/2 hrs. application time) =		.003
3/ $20.15 ÷ 3333 acres/hr. (16,000 acres ÷ 4.8 hrs. application time) =		.006

compared to $3.4 million for ULV malathion spraying. The malathion-PIB-7 combination has proven effective against the medfly in Israel; Brownsville, Texas; Chile; and in trials conducted in the Carazo-Masaya areas in Nicaragua.

While it is believed that the major medfly areas can be treated effectively by air applications of ULV malathion or malathion-PIB-7, a total of 3,740 square kilometers (924,150 acres) will require ground treatment (Table 6). In this area are high mountain peaks, deep ravines, and areas with adverse weather conditions which make it unsafe or impractical to apply materials effectively from the air. Table 8 presents input and cost data for ground treatment with malathion-PIB-7 spray applied from knapsack sprayers. The information shown was developed for a crew of 12 men--a supervisor, a truckdriver, and 10 men operating sprayers transported and supplied by a heavy-duty power wagon and trailer. The per-acre costs are shown for one application, eight applications, and projections for the entire 924,150 acres. A 50-workday period was assumed. It is recognized that horses and pack animals may be more practical than motorized equipment to transport men and materials in some of the most inaccessible areas, but no data were developed to cover this.

Table 9 shows the cities in Central America in which the medfly has been trapped, but which are not in the major treatment areas. These cities and towns comprise a total area of approximately 10,880 acres. Single-engine crop dusting aircraft are considered adapted for these small, noncontiguous areas. Table 10 reveals the inputs and costs of malathion applications for one and for eight applications, per acre, and for the 10,880 acres in cities and towns.

Sterile Fly Release

The release of sterile flies is an effective method for suppressing populations of medfly, and this method could be used as an important tool in an eradication program. Sterile fly release is appropriate primarily for areas accessible by low-level (200-500 foot) overflight by multiengine aircraft. Thus, in a sterile fly-release program, sterile flies could be released over a total area of 1,738,100 acres (7,034 km.^{2}).

The sterile fly release should begin about September at a rate of 4,000/km.^{2}/week, and continue for 6 months. Normally, the insecticide applications would begin at the beginning of the dry period and continue coverage for 8 weeks, one application per week.

Table 8. Estimated cost to spray medfly areas too hazardous for aircraft application in Central America, using ground spray equipment

		U.S. dollars per hour
Power wagon 4 wheel drive to haul men and supplies and pull trailer with 500 gal. water (rented).		12.00
Labor		
Supervisor	1 @ $1.75	1.75
Truck driver	1 @ $1.75	1.25
Knapsack spray operators	10 @ $1.00	10.00
Knapsack sprayers	10 @ $0.10 1/	1.00
TOTAL equipment and labor		26.00

	Per acre		Total--924,150 acres	
	1 appl.	8 appl.	1 appl.	8 appl.
	U.S. dollars			
Equipment and labor $26/hr. ÷ 20 acres/hr. (2 acres/hr./man x 10 men) 2/	1.30	10.40	1,201,395	9,611,160
Bait spray - 2 oz. malathion @ $0.04 and 8 oz. PIB-7 @ $0.01	.16	1.28	147,864	1,182,912
TOTAL	1.46	11.68	1,349,259	10,794,072

1/ Cost and maintenance assumed to be $50 for each back sprayer ÷ 500 hrs. of use (50 days @ 8 hrs. = 400 hrs. + 100 hrs. of respraying) or $0.10/hr.

2/ Based on square acres of coffee in rough terrain applying bait spray every 20 feet x 10 trips @ 3 minutes per trip = 30 min./acre or 2 acres/hr.

Table 9. Population and estimated area of cities outside of the major areas of medfly infestation that have medfly trapping histories which suggest self-sustaining medfly populations

Country	City	Population	Area[1] Km.^{2}	Area[1] Acres
Nicaragua (1971)[2]	Corinto	14,000	3.88	960
	El Viejo	24,000	5.18	1,280
	Chinandega	45,000	5.18	1,280
	Leon	76,000	7.77	1,920
	Rivas	21,000	3.88	960
	TOTAL	180,000	25.89	6,400
Costa Rica (1970)[3]	Liberia	14,200	5.18	1,280
	Filadelfia	4,250	2.59	640
	Santa Cruz	1,200	2.59	640
	Bagaces	9,800	2.59	640
	Las Canas	12,000	2.59	640
	Siquirres	7,000	2.59	640
	TOTAL	48,450	18.13	4,480
	GRAND TOTAL	228,450	44.02	10,880

1/ Estimates for treatment purposes.

2/ Censos Nacionale, 20 Abril 1971, cifras preliminares. Ministerio de Economia Industria y Comercio, Banco Central de Nicaragua. Boletin No. 1. Octubre 1971.

3/ Publicaciones 20-21 de la Republica de Costa Rica por Provincias, Cantones y Distritos, Estimacion al 1° de Abril y 1° de Julio de 1970. Direccion General de Estadistica y Censos, Ministerio de Industria y Industria y Comercio. Agosto 1971.

Table 10. Estimated cost to spray 10,880 acres in towns and cities which have medfly histories outside major areas of medfly infestations

	Per acre		Total--10,880 acres	
	1 appl.	8 appl.	1 appl.	8 appl.
	U.S. dollars			
Aircraft and personnel (contract)	0.32[1]	2.56	3,482	27,853
ULV malathion[2] 2 oz. @4¢/oz.	0.08	.64	870	6,963
TOTAL	.40	3.20	4,352	34,816

1/ Rate based upon air application of ULV malathion using single-engine aircraft with light loads.

2/ Concentration of ULV malathion reported to be non-injurious to property.

Costs of rearing, sterilizing, packaging, transporting, and releasing sterile flies are shown in Table 11. These cost estimates are for rearing 500 million flies weekly and dissemination or release of 400 million sterile flies weekly, which is sufficient for treating 1,000 square kilometers. The cost of $131.88 per million flies, derived from Table 11, was multiplied by the total number of million flies which would be required to cover the entire 7,034 km.^{2} treatable by air at the rate of 400,000 flies per km.^{2} each week (2,813.6 million flies per week/ $131.88 per million x 26 weeks = $9,647,497).

Comparison of the direct costs of the three alternative medfly eradication programs shows that sterile fly releases over large air-treatable areas would be most expensive, and one using ULV malathion would be least expensive.

Facilities and Equipment for Sterile Flies

The facilities and equipment necessary for rearing and sterilizing sufficient flies to cover the entire 7,034 km.^{2} area simultaneously would cost approximately $7.4 million (7,034 km.^{2} x $1.05 million per 1,000 km.^{2}; see Table 12). A multistage program, concentrating on a part of the entire area each year, would reduce these costs substantially. For example, facilities and equipment adequate to release sterile flies over a 1,758 km.^{2} area, implying a 4-year program to cover 7,034 km.^{2}, would cost only about $1.85 million, and could be operated at capacity for 4 years.

Costs of Comprehensive Eradication Programs

For meaningful comparison of the relative costs of the different methods of eradicating the medfly from Central America, cost estimates were developed for comprehensive 4-year programs using the three different methods. The programs differ only in the method of treatment of large areas suitable for treatment by aircraft.

In each program, it is assumed the treatment would be continued for the full period (8 weeks for insecticide sprays, and 6 months for sterile fly releases) over the entire medfly area in Central America. Treatment of cities and towns would be by air application of ULV malathion for all programs, and all ground treatment would be the spray application of malathion-PIB-7. Some retreatment of treated areas will undoubtedly be needed due to skips, bad weather, etc., and an allowance of 5 percent of total treatment costs is included for retreatment for each of the alternative programs in the year of initial treatment.

Table 11. Estimated annual costs of rearing, sterilizing, packaging, transporting and releasing medflies - annual costs of rearing 500 million and releasing 400 million flies per week

Item	Costs
	U. S. dollars
Medfly rearing	1,560,000
Airshipment of pupal to Nicaragua (2 DC3's 2 x wk)	33,280
Aerial release costs - (4 DC3's)	393,504
Sterile fly release material	221,400
Flight personnel (6 pilots, 2 supervisors, 10 crew)	177,600
Total rearing and release costs, annual	2,385,784
Rearing plant personnel	146,500
Pupal treatment and storage personnel	80,900
Rearing plant rent and overhead	80,000
Pupal treatment plant rent and overhead	50,000
Total plant personnel and overhead, annual	357,400
Total rearing, release and overhead costs - (20,800 million flies)	2,743,184
Cost per million flies	131.88

Table 12. Estimated costs of facilities and equipment for rearing, sterilizing, packaging, and dispersing Mediterranean fruit flies in Central America. Capacity: 500 million flies per week, for dispersing 400 million flies per week over 1000 $km.^2$

Item	Cost
Rearing facilities and equipment - Costa Rica	U. S. dollars
Rearing plant (fly proof) and office and lab space	500,000
Equipment and misc. supplies, money, fluorescent powders, etc.	200,000
Storage building	20,000
1 truck for pupal transport to airport	10,000
1 1-1/2 ton truck, 3 pickups, 2 sedans	20,000
Short wave radio equipment	1,000
Total	751,000
Pupal sterilization, packaging and dispersing facilities & equipment - Nicaragua	
Air conditioned building for pupal holding sterilization, packaging, storage, office and lab space	100,000
Irradiator (for treating flies in 2' x 2' x 2' boxes)	100,000
Air conditioning equipment	30,000
Truck for pupal transport (air conditioned)	15,000
Short wave radio	1,000
Misc. equipment - fork lift, conveyer belts	10,000
Automated pupal marketing, bag loading, bag closing and packaging machinery	30,000
2 pickups, 2 sedans	14,000
Total	300,000
Grand total, facilities and equipment	1,051,000

In each program, treatment of air-treatable areas, cities and towns, and ground application would all be scheduled in four stages, covering approximately one-fourth of the respective areas each year. The same cost of application per acre and the same number of applications are assumed to apply to this multistage program.

The sterile fly-release program, modified correspondingly for a 4-year program to cover 1,758 km.^{2} (434,400 acres) each year, would be increased the first year by $1.85 million for facilities and equipment for rearing, sterilizing, and distributing 700 million flies a week. Costs in the second and subsequent years would not include anything for facilities and equipment, but would include an estimate that 10 percent of the area treated each year would require retreatment the following year. It is assumed that essentially complete eradication in a given area would be achieved the second year. These costs do not include an estimate for possible lower costs due to increased efficiency in operation for the second and subsequent years.

Estimated annual and cumulative costs for a comprehensive medfly program in Central America by the three methods are shown in Tables 13, 14, and 15. Since 1-year trapping in advance of beginning an eradication program is needed, and time is needed for construction of facilities, obtaining equipment, and organizing and training personnel, the first year of any program would be devoted to these preparatory activities, with actual eradication efforts beginning the second year. In each of the next 4 years, an eradication program would be concentrated on one-fourth of the medfly-infested area. Because of the probable necessity for retreatment of persistent localized infestation in the second year to achieve complete eradication, estimates of costs of retreatment or mop-up operations are shown for 1 year after the major program. This suggested program thus would cover a period of 6 years, including 1-year preparatory trapping, 4 years of major eradication efforts, and 1 year of final mop-up.

The total cost of a comprehensive eradication program, including costs of retreatment and the monitoring program but not including the survey trapping program, is estimated at $21.8 million using ULV malathion spray on air-treatable areas, $25.7 million using malathion bait spray, and $30.8 million using sterile fly releases (including the cost of equipment and facilities). These estimates probably can be considered as the maximum cost since they include total estimated costs of treatment, allowance for retreatment, and the monitoring program. In the actual execution of such a program, it is likely the monitoring program would

Table 13. Estimated annual costs of medfly eradication program in Central America using technical insecticide sprays, 4-year program and followup

Year	Spray program				Monitor	Total	
	Large Areas	Cities & Towns	Ground	Retreatment 1/		Annual	Cumulative
	Thousand U.S. dollars						
1	-	-	-	-	-	-	-
2	845	9	2,699	178	1,234	4,965	4,965
3	845	9	2,699	534	1,357	5,444	10,409
4	845	9	2,699	534	1,357	5,444	15,853
5	845	9	2,699	534	1,357	5,444	21,297
6	-	-	-	356	123	479	21,776
TOTAL	3,380	36	10,796	2,136	5,428	21,776	

1/ Includes retreatment in same year of 5 percent of area receiving initial treatment; retreatment in following year of 10 percent of area receiving initial treatment.

Table 14. Estimated annual costs of medfly eradication program in Central America using insecticide plus bait sprays 4-year program and followup

Year	Spray program				Monitor	Total	
	Large Areas	Cities & Towns	Ground	Retreatment 1/		Annual	Cumulative
	Thousand U.S. dollars						
1	-	-	-	-	-	-	-
2	1,689	9	2,699	220	1,234	5,851	5,851
3	1,689	9	2,699	660	1,357	6,414	12,265
4	1,689	9	2,699	660	1,357	6,414	18,679
5	1,689	9	2,699	660	1,357	6,414	25,093
6	-	-	-	440	123	563	25,656
TOTAL	6,756	36	10,796	2,640	5,428	25,656	

1/ Includes retreatment in same year of 5 percent of area receiving initial treatment; retreatment in following year of 10 percent of area receiving initial treatment.

Table 15. Estimated annual costs of medfly eradication sterile fly release and insecticide sprays, 4-year program and followup

Year	Sterile Flies		Insecticide			Monitor	Total	
	Facilities and Equipment	Rearing and Release	Air Cities	Ground	Retreatment 1/		Annual	Cumulative
	Thousand U.S. dollars							
1	1,846	-	-	-	-	-	1,846	1,846
2	-	2,412	9	2,699	256	1,234	6,610	8,456
3	-	2,412	9	2,699	768	1,357	7,245	15,701
4	-	2,412	9	2,699	768	1,357	7,245	22,946
5	-	2,412	9	2,699	768	1,357	7,245	30,191
6	-	-	-	-	512	123	635	30,826
TOTAL	1,846	9,648	36	10,796	3,072	5,428	30,826	

1/ Includes retreatment in same year of 5 percent of area receiving initial treatment; retreatment in following year of 10 percent of area receiving initial treatment.

indicate that certain areas were free of the medfly and treatment in that area could be suspended. Thus the actual costs of treatment could be less than estimated.

Costs of the closely-related survey trapping program, however, are not included, and would be in addition to the direct costs of any of the eradication programs. The survey trapping program is considered essential throughout the Central American countries, independent of any medfly eradication program (although the survey program would indicate the general areas where the medfly is present).

The estimated cost is only one of several factors which must be considered in evaluating these alternative medfly eradication programs. Although a program using ULV malathion sprays would be the least expensive, this method has not yet been proven to be completely effective in an eradication program. Furthermore, 100 percent blanket coverage of large areas with malathion would have a direct impact on other insect species, and some of the effects could harm fruits or other crops, birds, animals, and humans. A similar impact on other insects, etc., would result from using malathion plus bait sprays, but it would not be as great since the coverage would not be 100 percent. An eradication program using sterile flies for areas suitable for low-level aerial release would have the least impact on other insects, crops, birds, etc., but this is the most costly.

In view of the unproven effectiveness of ULV malathion in an eradication program, and a possibility of public or official reaction against undesirable environmental impact of widespread aerial application of technical or bait insecticides, an eradication program incorporating the use of sterile fly releases probably represents the most likely program and also the maximum cost that would be involved.

IMPACT OF THE MEDFLY ON FRUIT PRODUCTION AND MARKETING IN CENTRAL AMERICA

QUANTITY AND VALUE OF FRUIT PRODUCTION

In order to evaluate the impact of the medfly on fruit production, it is necessary to know, at least approximately, the quantity and value of the fruits produced, as well as the damage caused by the medfly. There are few data available on fruit production in Central America. Consequently, estimates of fruit production were developed by the survey team using fragmentary and uncertain data available on production and per capita consumption, observation of markets and production areas, and judgement of persons familiar with fruit production and/or consumption characteristics in each country.

In order to utilize the few data available for as recent a complete year as possible, estimates were developed for the calendar year 1970 (Tables 16-22).

Those fruits subject to attack by the medfly are grouped separately from nonsusceptible fruits. This permits evaluation of the impact of the fly on those fruits directly affected by the fly, as well as on the entire fruit industry. Although vegetables are rarely attacked by the medfly, data on vegetables were also developed because of the close relationship of production and marketing of fruits and vegetables.

In addition, since coffee is a primary host of the medfly and is grown extensively in Central America, data on coffee production are also included to show its relative importance and value.

With the exception of bananas, fruits and vegetables in Central America are produced principally for local consumption. There is little large-scale, commercial production of fruits and vegetables.

Bananas are produced principally for the export market by a few companies on extensive commercial plantations. Relatively few of these commercially-produced bananas are sold on local markets in the countries where they are produced. This is partly because the local markets are small and can absorb only a small part of the bananas produced, and partly because the banana plantations are oriented strongly toward export rather than local markets. In some instances, sale of bananas from the large plantations of foreign firms is limited to export markets.

Table 16. Estimated consumption, foreign trade, production, and value of fruits and vegetables in Central America - Costa Rica, 1970.

	Consumption		Imports	Exports	Production		
	Per capita	Total			Quantity	Value	
						Unit	Total
	Kg/cap.	M.T.	M.T.	M.T.	M.T.	$/M.T.	$1000
Oranges & Mandarins	25.0	43,500	1,000		42,500	$ 57	$2,423
Grapefruit	1.0	1,700	-		1,700	50	85
Limes	2.0	3,500	-		3,500	100	350
Total citrus	28.0	48,700	1,000		47,700	60	2,858
Avocado	5.0	8,700	-		8,700	100	870
Mango	1.0	1,700	-		1,700	100	170
Papaya	2.0	3,500	-	50	3,500	158	561
Other fruit 1/	1.7	3,000	1,100	2,500	4,400	150	660
Subtotal		65,600	2,100	2,550	66,050		5,119
Tomatoes	10.0	17,400	500	325	17,225	286	4,926
Melons	1.0	1,700	50		1,650	60	99
Watermelon	2.0	3,500	100		3,400	60	204
Pineapple	10.0	17,405	400	145	17,150	140	2,121
Bananas	15.0	29,000	-	858,500	887,500 2/	92	81,650
Total-fruits, melons & tomatoes		134,605	3,150	861,520	992,975		94,119
Plantain	16.5	28,700	-	11,820	40,520	60	2,431
Potatoes & root	20.0	34,800	4,100	40	30,740	100	3,074
Other veg.	10.0	17,400		1,410	18,810	200	3,762
Total-roots and vegetables		80,900	4,100	13,270	90,070		9,267
Coffee	4.4	7,700	-	69,100	76,800	1051	80,731

1/ Includes all fruit not otherwise specified. Imports and exports may also include quantities of fruits shown individually.

2/ Exclusive of feed use, waste and losses.

6.65 Colones = U. S. $1.00 (official)

Table 17. Estimated consumption, foreign trade, production, and value of fruits and vegetables in Central America - El Salvador, 1970.

	Consumption		Imports	Exports	Production		
	Per capita	Total			Quantity	Value	
						Unit	Total
	Kg/cap.	M.T.	M.T.	M.T.	M.T.	S/M.T.	$1000
Oranges & Mandarins	20.0	68,500	2,110	100	$66,490	87	$5,785
Grapefruit		-					
Limes	1.5	5,150	20		5,130	117	600
Total citrus		73,650	2,130	100	71,620	89	6,385
Avocado	6.0	20,600	1,000	200	19,800	141	2,792
Mango	5.0	17,100	10	80	17,170	105	1,803
Papaya	2.0	6,900	10		6,890	76	524
Other fruit 1/	4.2	14,300	2,660		11,640	189	2,200
Subtotal		132,550	5,810	380	127,120		13,704
Tomatoes	6.6	22,600	1,810	790	21,580	125	2,698
Melons	4.0	13,700	-	1,640	15,340	87	1,335
Watermelons	5.0	17,100	255	3,825	20,670	59	1,220
Pineapple	10.0	34,300	65		34,235	85	2,910
Bananas	7.5	25,700	17,530		8,170	81	662
Total-fruits, melons & tomatoes		245,950	25,470	6,635	227,115		22,529
Plantain	6.0	20,600	11,990		8,610	72	620
Potatoes & root	7.5	25,700	9,670		16,030	100	1,603
Other veg.	8.4	28,800	13,820		14,980	200	2,996
Total-roots and vegetables		75,100	35,480		39,620		5,219
Coffee	2.5	9,300	-	120,900	130,200	980	127,596

1/ Includes all fruit not otherwise specified. Imports and exports may also include quantities of fruits shown individually.

2.50 Colones = U. S. $1.00

Table 18. Estimated consumption, foreign trade, production, and value of fruits and vegetables in Central America - Guatemala, 1970.

	Consumption per capita	Consumption Total	Imports	Exports	Production Quantity	Production Value Unit	Production Value Total
	Kg/cap.	M.T.	M.T.	M.T.	M.T.	S/M.T.	$1000
Oranges & Mandarins	10.0	53,000	1,000	500	52,500	S 55	$2,888
Grapefruit	1.5	8,000	200	-	7,800	50	390
Limes	1.5	8,000	-	-	8,000	100	800
Total citrus	13.0	69,000	1,200	500	68,300	60	4,078
Avocado	5.0	26,500	-	250	26,750	35	936
Mango	5.0	26,500	-	-	26,500	22	583
Papaya	2.0	10,600	-	-	10,600	52	551
Apples, pears & peh.	2.0	10,500	-	2,500	13,000	125	1,625
Other fruit 1/	7.5	36,300	-	3,500	39,800	150	5,970
Subtotal		179,400	1,200	6,750	184,950		13,743
Tomatoes	10.0	51,000	-	2,000	53,000	100	5,300
Melons	.5	2,600			2,600	53	138
Watermelon	2.0	10,600	200		10,400	70	728
Pineapple	5.0	26,500			26,500	87	2,306
Bananas	10.0	53,000		163,500	216,500 2/	75	16,238
Total-fruits melons & tomatoes		323,100	1,400	172,250	493,950		38,453
Plantain	7.0	37,200		15,000	52,200	60	3,132
Potatoes & root	8.0	42,400		3,000	45,400	100	4,540
Other veg.	5.0	26,500		5,000	31,500	200	6,300
Total-roots and vegetables		106,100		23,000	129,100		13,972
Coffee	3.0	15,000		95,400	110,400	1019	112,512

1/ Includes all fruit not otherwise specified. Imports and exports may also include quantities of fruits shown individually.

2/ Exclusive of feed use, waste, and losses.

1 Quetzal = U. S. $1.00

Table 19. Estimated consumption, foreign trade, production and value of fruits and vegetables in Central America - Honduras, 1970.

	Consumption		Imports	Exports	Production		
	Per capita	Total			Quantity	Value	
						Unit	Total
	Kg/cap.	M.T.	M.T.	M.T.		$/M.T.	$1000
Oranges & Mandarins	15.0	40,600	10	990	41,580	$ 55	$2,287
Grapefruit	2.5	6,800	-	7,150	13,950	50	698
Limes	1.5	4,100	-	100	4,200	100	420
Total citrus	19.0	51,500	10	8,240	59,730	57	3,405
Avocado	2.0	5,400	110	-	5,290	100	529
Mango	10.0	27,100	10	10	27,100	100	2,710
Papaya	2.5	6,800	-	-	6,800	60	408
Other fruit 1/	5.0	13,500	4,120	11,200	20,580	150	3,087
Subtotal		104,300	4,250	19,450	119,500		10,139
Tomatoes	1.5	4,100	280	10	3,830	200	766
Melons	.5	1,400	-	10	1,410	60	85
Watermelon	1.5	4,100	40	100	4,160	60	250
Pineapple	2.5	6,800	-	4,170	10,970	100	1,097
Bananas	15.0	40,600	-	799,200	839,800 2/	90	75,582
Total-fruits melons & tomatoes		161,300	4,570	822,940	979,670		87,919
Plantain	40.0	108,400	-	13,180	121,580	60	7,295
Potatoes & root	15.0	40,600	2,660	-	37,940	194	7,360
Other veg.	8.5	23,000	-	30	23,030	200	4,606
Total-roots and vegetables		172,000	2,660	13,210	182,550		19,261
Coffee	3.5	10,000	-	25,580	35,580	993	35,335

1/ Includes all fruit not otherwise specified. Imports and exports may also include quantities of fruit shown individually.

2/ Exclusive of feed use, waste and losses.

2 Lempiras = U. S. $1.00

Table 20. Estimated consumption, foreign trade, production, and value of fruits and vegetables in Central America - Nicaragua, 1970.

	Consumption: Per capita	Consumption: Total	Imports	Exports	Production: Quantity	Production: Value: Unit	Production: Value: Total
	Kg/cap.	M.T.	M.T.	M.T.	M.T.	$/M.T.	$1000
Oranges & Mandarins	23.5	46,000	-	-	46,000	$ 100	$4,600
Grapefruit	1.0	1,900	-	-	1,900	53	101
Limes	.5	1,000	-	-	1,000	124	124
Total citrus	25.0	48,900	-	-	48,900	99	4,825
Avocado	1.0	1,900	-	50	1,950	500	975
Mango	5.0	9,600	-	-	9,600	127	1,219
Papaya	3.0	5,800	-	-	5,800	158	916
Other fruits 1/	7.0	13,800	6,400	-	7,400	150	1,110
Subtotal		80,000	6,400	50	73,650		9,045
Tomatoes	3.0	5,800	-	500	6,300	195	1,229
Melons	.5	1,000	-	50	1,050	60	63
Watermelons	2.0	3,800	-	100	3,900	60	234
Pineapple	3.0	5,800	-	400	6,200	86	533
Bananas	10.0	19,000	-	30,000	49,000 2/	80	3,920
Total-fruits melons & tomatoes		115,400	6,400	31,100	140,100		15,024
Plantain	50.0	93,100	-	-	93,100	60	5,586
Potatoes & root	10.0	23,300	4,200	-	19,100	100	1,910
Other veg.	12.0	23,000	3,000	-	20,000	200	4,000
Total-roots and vegetables		139,400	7,200	-	132,200		11,496
Coffee	2.5	4,800	-	28,200	33,000	1,060	34,974

1/ Includes all fruit not otherwise specified. Imports and exports may also include quantities of fruits shown individually.

2/ Exclusive of feed use, waste and loss.

7 Cardobas = U. S. $1.00

Table 21. Estimated consumption, foreign trade, production, and value of fruits and vegetables in Central America - Panama, 1970.

	Consumption		Imports	Exports	Production		
	Per capita	Total			Quantity	Value	
						Unit	Total
	Kg/cap.	M.T.	M.T.	M.T.	M.T.	$/M.T.	$1000
Oranges & Mandarins	25.0	36,600	-	-	36,600	$ 70	$2,562
Grapefruit	1.6	2,400	-	-	2,400	72	173
Limes	2.0	2,900	-	-	2,900	230	667
Total citrus	28.6	41,900	-	-	41,900	81	3,402
Avocado	4.5	6,600	-	-	6,600	90	594
Mango	2.5	3,700	-	-	3,700	100	370
Papaya	5.0	7,300	-	-	7,300	135	986
Other fruit 1/	7.0	10,300	3,000	-	7,300	150	1,095
Subtotal		69,800	3,000	-	66,000		6,447
Tomatoes	15.0	22,000	-	-	22,000	340	7,480
Melons	2.0	2,900	-	-	2,900	60	174
Watermelons	2.5	3,700	-	-	3,700	60	222
Pineapple	3.5	5,100	-	-	5,100	204	1,040
Bananas	20.0	29,300	-	435,000	464,300 2/	75	34,822
Total-fruits melons & tomatoes		132,800	3,000	435,000	564,800		50,185
Plantain	30.0	49,000	-	1,000	50,000	48	2,400
Potatoes & root	25.0	36,600	-	-	36,600	75	2,745
Other veg.	5.0	20,000	-	-	20,000	237	4,740
Total-roots and vegetables		105,600	-	1,000	106,600		9,885
Coffee	2.5	4,000	-	1,150	5,150	1022	5,265

1/ Includes all fruit not otherwise specified. Imports and exports may also include quantities of fruits shown individually.

2/ Exclusive of feed use, waste and loss.

1 Balboa = U. S. $1.00

Table 22. Estimated consumption, foreign trade and production of fruits and vegetables, in Central America-Total (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama.) 1970.

	Consumption		Imports	Exports	Production		
	Per capita	Total			Quantity	Value	
						Unit	Total
	Kg/cap.	M.T.	M.T.	M.T.	M.T.	$/M.T.	$1000
Oranges & Mandarins	17.2	288,200	4,120	1,590	285,670	$ 72	$20,545
Grapefruit	1.7	20,800	200	7,150	27,750	52	1,447
Limes	1.5	24,650	20	100	24,730	120	2,961
Total citrus	20.4	333,650	4,340	8,840	338,150	74	24,953
Avocado	4.2	69,700	1,110	500	69,090	97	6,696
Mango	5.2	85,700	20	90	85,770	66	6,855
Papaya	2.5	40,900	10	50	40,940	96	3,946
Apples, pears, pch.	.8	10,500	1/	2,500	13,000	125	1,625
Other fruit 2/	5.5	91,200	17,200	17,200	91,120	155	14,122
Subtotal	38.5	631,650	22,760	29,180	638,070		58,197
Tomatoes	7.5	122,900	2,590	3,625	123,935	181	22,399
Melons	1.5	23,300	50	1,700	24,950	76	1,894
Watermelons	2.8	42,800	595	4,025	46,230	62	2,858
Pineapple	6.0	95,905	465	4,715	100,155	99	10,007
Bananas	11.9	196,600	17,530	2,286,200	2,465,270	86	212,874
Total-fruits melon & tomatoes	68.2	1,113,155	43,990	2,329,445	3,398,610		308,229
Plantain	22.1	337,000	11,990	41,000	366,010	59	21,464
Potatoes & root	11.2	203,400	20,630	3,040	185,810	114	21,232
Other veg.	7.7	138,700	16,820	6,440	128,320	206	26,404
Total-roots and vegetables	41.1	679,100	49,440	50,480	680,140		69,100
Total-fr. & vegs.		1,792,255	93,430	2,379,925	4,078,750		377,329
Coffee		50,800	-	340,330	391,130	1014	396,413

1/ Included in other fruit.

2/ Includes all fruits not otherwise specified. Imports and exports may include quantities of the fruits shown individually.

Based on indications of local market wholesale prices, total value of fruit production in Central America is estimated to be about $310 million for 1970, of which about $210 million are bananas. The value of fruits susceptible to attack by the medfly is estimated at about $80 million. The value of other nonsusceptible fruits and melons (melons, watermelons, and pineapples) is about $15 million. By comparison, Central American coffee production for 1970 is valued at nearly $400 million.

The most important individual fruit other than bananas in quantity and value of production is citrus, principally oranges and mandarins. The value of the production of oranges and mandarins is estimated at about $20 million. The value of other citrus, principally grapefruit and limes, is estimated to be $4 million.

PRESENT MARKETS AND POTENTIAL

Fruits produced in Central America are nearly all consumed in the countries. There is some inter-country movement, and a small volume of exports outside the area, mostly to the United States and Canada.

Per capita consumption of fruits and melons in Central America and Panama is estimated at about 61 kg., or 134 pounds annually. This is roughly equivalent to one and a half medium-sized fruits per person daily, and includes all fruit, whether purchased in the market or picked from dooryard trees. It is possible that, for individual fruits, as much as half or more of this estimated consumption comes from dooryard or naturally-occurring plantings.

Only a small amount of fruit consumed in Central America is processed. As with fruit production, there are few data available on processing of fruit.

POTENTIAL FOR DEVELOPMENT

In terms of gross weight, the present level of fruit consumption per capita appears to leave potential for future production for consumption within Central America. Maintaining per capita consumption at present levels would be a minimum goal, and increases in consumption of individual fruits would be desirable. There especially appears to be potential for expansion of consumption of processed fruits, which would be suitable for export as well as domestic consumption.

Development or expansion of export markets for fruits and vegetables is almost universally attractive, at least in principal, to persons involved or interested in development of Central American countries. Because of its proximity, the vast U.S. market is particularly attractive for developing production of fruits for export. However, production costs in Central America per unit of citrus produced (the principal fruit crop) are still relatively high compared to the highly efficient operations in Florida, and there is presently very little commercial production of other fruit crops. Although there is also potential for increased exports to Canada, Europe, and other countries, practically all exports would have to compete with fruit production in the importing countries as well as exports from other countries into these markets. Other barriers to be overcome in importing countries are quarantine and other restrictions or requirements for imports, particularly in countries where there is domestic production.

Also, the present production, handling, packing, and marketing practices are not appropriate to support large-scale export operations. Thus, development of the potential in expanded export markets will depend on the development of a larger, efficient, and reliable production base, as well as a greatly modified marketing system.

An annual physical increment of 5 percent is probably the minimum rate of development of fruit production in Central America which can be expected. This rate would be sufficient to maintain the per capita fruit consumption in the region, with substantial percentage increments (20-40 percent) in exports, which presently are at a very low absolute level.

More rapid development of fruit production in Central America is possible, however. For example, production from a large commercial citrus planting in western Panama in the medfly area is not included in the estimates developed for 1970, but is coming into production this year (1972). This will increase total citrus production in Central America by one-third; practically all will go into export in concentrated form.

Consequently, for projecting potential fruit production and losses, the new Panama citrus production is included beginning with 1972, and further projections are made on the basis of annual increments of 5 percent in total fruit production.

Projection of coffee production is based on annual increments of 2.5 percent, the rate estimated by FAO for projections of world coffee demand (FAO, "Agricultural Commodity Projections, 1970-1980" Volume 1, p 220. CCP-71/20 Rom. 1971).

ESTIMATED LOSSES DUE TO THE MEDFLY

Economic damage or loss of fruit due to attack by the medfly in infested areas of Central America appears to be limited largely to oranges and grapefruit. Mandarins are the most severely attacked, and in Central Meseta of Nicaragua, it is estimated that 50 percent of the mandarin crop is lost due to the medfly. In the same area of Nicaragua, sweet oranges suffer about 10 percent loss.

Mandarins are popular in Nicaragua and constitute an estimated 60 percent of the total citrus crop. An average of 34 percent of the Nicaraguan orange and mandarin crop is damaged by the medfly.

In Costa Rica and Panama, it was estimated that 20 percent of the orange crop is lost due to damage by the medfly. (The large citrus plantation near Boquete was not in production in 1970 and is not reflected in these production and loss estimates.)

In estimating losses for Panama, only the production in western Panama which is infested by the medfly was included. It was estimated that about a third of Panama's total citrus production occurs in this infested area.

The proportion of grapefruit lost because of medfly damage varied somewhat from oranges. In Costa Rica, 15 percent were estimated to be damaged, 25 percent in Nicaragua and 35 percent in western Panama.

A number of other fruits are hosts of the medfly and serve to maintain the population during periods when citrus hosts are not available. The infestation of these fruits is usually limited to neglected and abandoned overripe fruit which are of little or no real economic value.

Since infestation by medfly larvae is at least partly a cause of the loss of value of overripe fruit, however, it would appear reasonable to consider loss of this fruit an additional economic loss due to the medfly. If we assign a nominal 2 percent for damage of this nature, this would be an additional $.2 million loss due to the medfly. The total value of these fruits, other than oranges and grapefruit produced in the medfly-infested areas, is estimated at $8.2 million for 1970 (Table 23).

Medfly larvae can almost always be found in some well-ripened coffee berries in infested areas, and affect an estimated 5 percent of the total coffee crop. The economic damage to coffee is reflected largely in lower quality and lower price of coffee beans from medfly-infested cherries

thrown in with other sticktights. It is estimated that about 1 percent of the value of total coffee crop in infested areas--about $1.2 million--was lost due to the medfly (See Table 25, page 82).

Table 23. Estimated value of actual losses due to medfly in Central America in 1970

Crop damaged[1]	Value of production	Damage	Value of damage
	Thous. dollars	Percent	Thous. dollars
Oranges & mandarins			
Costa Rica	2,423	20	485
Nicaragua	4,600	34	1,564
Panama[2]	854	20	171
Subtotal	7,877	28	2,220
Grapefruit			
Costa Rica	85	15	13
Nicaragua	101	25	25
Panama[2]	57	35	20
Subtotal	243	24	58
Other fruit			
Costa Rica	2,611	2	52
Nicaragua	4,344	2	87
Panama[2]	1,237	2	25
Subtotal	8,192	2	164
Total fruit susceptible			
Costa Rica	5,119		550
Nicaragua	9,045		1,676
Panama[2]	2,148		216
Total	16,312		2,442

1/ Crops showing evidence of economic damage due to the medfly in areas where the medfly is now present.

2/ One-third of Panama's total production; the estimated quantity produced in western Panama areas infested by medfly.

Based on these estimates of percentages of the crop lost, applied to the estimated value of the production of oranges, grapefruit, and other susceptible fruit in the medfly area, the value of losses due to the medfly in Central America in 1970 was approximately $2.4 million (Table 23).

Applying the average percentage losses observed in the areas now infested by the medfly (28 percent of all oranges, 24 percent of grapefruit, and 2 percent of other susceptible fruit) to total production of these fruits in Central America and Panama, a total potential loss in Central America of $6.8 million annually is indicated, of which $6.1 million would be citrus (Table 24).

Table 24. Estimated potential losses due to medfly in Central America and Panama

Crop	Value of production	Estimated damage	Value of damage
	Thousand dollars	Percent	Thousand dollars
Oranges & Mandarins	20,545	28	5,753
Grapefruit	1,447	24	347
Total citrus	21,992	27.7	6,100
Other fruit	36,205	2	724
Total	58,197		6,824

It should be emphasized that these estimates of potential losses from the medfly assume the same rate of damage would occur in new areas as that experienced in areas where the medfly now is found.

Since the Mexican fruit fly (Anastrepha ludens) is now a fruit pest in most of these areas not infested by the medfly, both flies would be in competition for many of the same fruit crops. The nature and degree of interaction or competition of the medfly and Mexican fruit fly on citrus or other fruit infested with both is not presently known. Based on observations of competition between medfly and Oriental fruit fly in Hawaii, it is considered likely that the damage of two different fly species would not be additive. That is, if the medfly moved into an area infested by the Mexican fruit fly (which attacks 30 percent of the orange crop), the medfly would probably not cause an additional 28 percent loss.

Furthermore, spray applications to control one would also control the other. Since it is common practice to spray commercial citrus plantings for control of Anastrepha where this fly occurs, it appears that invasion of these areas by the medfly would cause relatively little additional crop loss in citrus.

Considering that the Mexican fruit fly is now established in all non-medfly areas in Central America, and that the medfly plus the Mexican fruit fly will result in some fruit damage in addition to that caused by either fly alone, it does not appear unreasonable to assume the medfly moving into new areas in Central America would cause damage to citrus at an average rate one-half of that observed in presently infested areas.

The 2 percent medfly damage to other susceptible fruit species appears to be reasonable for new areas because of the low rate of infestation and differences in preference for the host fruits, compared with the Mexican fruit fly preferences.

Estimates of the total potential losses due to the medfly on this basis are shown in Table 25.

The estimates of loss due to the medfly (shown in Table 25) appear to be a reasonable indication of the impact of the medfly in Central America. In the absence of a control or eradication program in addition to present activities, the medfly can be expected to spread into other areas throughout Central America.

In summary, the direct economic loss due to medfly damage to fruit in medfly-infested areas of Central America is estimated for 1970 at approximately $2.4 million, of which $2.1 million is citrus. At the same rates of loss, potential losses for the entire Central American area would be $6.8 million ($6.1 million citrus) if the medfly were present in all of Central America. Allowing for lower rates of damage to citrus if the medfly spread into new areas, due to the presence there of other fruit flies (principally Anastrepha), losses potentially would be $4.9 million ($4.2 citrus) for all of Central America for 1970. This includes the estimated actual losses in the medfly area ($2.4 million) plus $2.5 million potential additional losses should the medfly spread to other areas in Central America. In addition to fruit crops, loss of coffee due to the medfly is estimated at $1.2 million in presently-infested areas, plus a potential $2.8 million in other areas.

Assuming the same rates of damage, the citrus industry of British Honduras would suffer $1 million annually and Mexico $5 million, should the medfly move into these countries. Also, Mexican coffee producers would lose $1.8 million.

Table 25. Estimated present and potential losses due to the Mediterranean fruit fly in Central America and Panama for 1970

Crop	Value of production	Estimated damage	Value of damage
	Thous. dollars	Percent	Thous. dollars
Oranges & mandarins			
Medfly areas	7,877	28	2,220
Other areas	12,668	14	1,774
Subtotal	20,545		3,994
Grapefruit			
Medfly areas	243	24	58
Other areas	1,204	12	144
Subtotal	1,447		202
Other susceptible fruit			
Medfly areas	8,192	2	164
Other areas	28,013	2	560
Subtotal	36,205		724
Total susceptible fruit			
Medfly areas	16,312	15.0	2,442
Other areas	41,885	5.9	2,478
Total	58,197		4,920
Coffee			
Medfly areas	117,460	1	1,175
Other Areas	278,953	1	2,790
Total	396,413		3,965

The potential damage to the U.S. fruit industry would be much greater. At one-half the damage rates observed in Central America, the medfly damage to the U.S. citrus industry would approximate $85 million annually. Deciduous fruits are more susceptible to attack by the medfly, and losses could amount to more than $200 million annually, a third of total value of production. As long as the medfly remains in Central America, or even in Mexico, its impact on the U.S. fruit industries can be largely academic. Should the medfly become established in the United States, however, it would immediately become an extremely costly threat.

BENEFITS RELATIVE TO COSTS OF ERADICATING THE MEDFLY IN CENTRAL AMERICA

In order to arrive at an estimate of losses which could be avoided by elimination of the medfly, the production of oranges, grapefruit, and other host fruits of the medfly were projected through 1980. Estimated values of production and losses of these fruits for 1970 in the area presently infested by the medfly and other areas in Central America were used as a base for these projections. (Table 26)

For the purpose of projecting, an assumption of 5 percent annual increment of fruit production was used throughout the period of projection. The same rates of damage by the medfly in 1970 were used for the entire period of projection, so that losses also increased by an annual increment of 5 percent.

Any program intended to eradicate or control the medfly could not be initiated before 1973, and both fruit production and losses can be expected to be larger in 1973 than in 1970. Consequently, the costs and benefits (fruit losses avoided) of such a program shown in Table 27 begin with 1973, the first year of the program, and continue for 8 years. It is assumed the eradication would be complete after 6 years, but benefits would continue after that.

Benefits from a medfly eradication program are shown on two bases. The first includes projection of estimates of savings (losses avoided) only in the area now infested by the medfly. The second assumes the medfly would spread throughout Central America by 1975, and includes projected estimates of losses applicable to the entire area (Table 27, also see Table 25).

Since it is suggested that one-fourth of the area be covered each year, completing coverage of the entire area in 4 years, the benefits would occur accordingly. Thus, in 1974, the second year of the program (the first year is occupied by the survey trapping program and preparation of medfly rearing facilities), one-fourth of the medfly area would be treated and the benefits (savings) would be one-fourth of the estimated losses for 1974 shown in Table 26 (1/4 x $5,791 = $1,448).

In the third year of the program (1975), an additional one-fourth of the area would be treated, so benefits that year would be one-half of the estimated losses for the medfly area ($\frac{1}{2}$ x $6,048 = $3,024).

Table 26. Projected value of production and loss of oranges, grapefruit, and other fruit susceptible medfly damage, 1970-1980

		Value of production 1/				Value of loss 2/	
		Oranges	Grape-fruit	Other fruit	Coffee	By Area	Total C. A.
		Thousand dollars					
1970	a 3/	7,877	243	8,192	117,460	3,603	8,871
	b 4/	12,668	1,204	28,013	278,953	5,268	
1971	a	8,270	255	8,602	120,397	3,753	9,214
	b	13,301	1,264	29,414	285,927	5,461	
1972	a	13,683 5/	268	9,032	123,407	5,310	10,973
	b	13,966	1,327	30,885	293,075	5,663	
1973		14,367	281	9,484	126,492	5,545	11,418
	b	14,664	1,393	32,429	300,402	5,873	
1974	a	15,085	295	9,958	129,654	5,791	11,882
	b	15,397	1,463	34,050	307,912	6,091	
1975	a	15,839	310	10,456	132,895	6,048	12,362
	b	16,167	1,536	35,752	315,610	6,319	
1976	a	16,631	326	10,979	136,217	6,317	12,873
	b	16,975	1,613	37,540	323,500	6,556	
1977	a	17,463	342	11,528	139,622	6,598	13,401
	b	17,824	1,694	39,417	331,588	6,803	
1978	a	18,336	359	12,104	143,113	6,893	13,953
	b	18,715	1,779	41,388	339,878	7,060	
1979	a	19,253	377	12,709	146,691	7,202	14,530
	b	19,651	1,868	43,457	348,375	7,328	
1980	a	20,216	396	13,344	150,358	7,526	15,134
	b	20,634	1,961	45,630	357,084	7,608	

1/ Projected on basis of annual increments of 5 percent, beginning with estimates for 1970; except coffee, for which 2.5 percent annual increment is used.

2/ Aggregate value of losses based on percentage losses for medfly areas and other areas as follows: (notes 3/ and 4/)

3/ a = Present medfly areas, oranges - 28 percent; grapefruit - 24 percent; other susceptible fruits - 2 percent; coffee - 1 percent.

4/ b = Other areas in C.A., oranges - 14 percent; grapefruit - 12 percent; other susceptible fruits - 2 percent; coffee - 1 percent.

5/ Increased by $5 million due to large citrus plantation in Panama coming into production.

Table 27. Comparison of estimated costs and benefits of a medfly eradication program in Central America

Year	Cost[1]		Benefits-present Medfly area[2]		Benefits-total Central America[2]	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
	Thousand dollars					
1 (1973)	1,846	1,846	-	-	-	-
2 (1974)	6,610	8,456	1,448	1,448	2,971	2,971
3 (1975)	7,245	15,701	3,024	4,472	6,184	9,155
4 (1976)	7,245	22,946	4,738	9,210	9,655	18,810
5 (1977)	7,245	30,191	6,598	15,808	13,401	32,211
6 (1978)	635	30,826	6,893	22,701	13,953	46,164
7 (1979)	-	30,826	7,202	29,903	14,530	60,694
8 (1980)	-	30,826	7,526	37,429	15,134	75,828

1/ From Table 15.

2/ Computed from Table 26.

Similarly, the fourth year of the program, three-fourths of the area would be covered, and benefits would be three-fourths of the estimated losses for that year (3/4 x $6,317 = $4,738). For the fifth and subsequent years, the benefits would be the total amount of estimated losses avoided since the medfly would be eradicated in the fifth year. The same procedure is followed for projecting estimated benefits to all Central America.

If the benefits (fruit losses avoided) are considered only to apply to the area presently infested by the medfly, cumulative benefits would approach cumulative costs (not including costs of the continuing survey program) the seventh year after initiation of the program (1979), and benefits would exceed costs in the eighth year.

Considering the possibility that, in the absence of any program, the medfly would spread throughout Central America by 1975, benefits applicable to all Central America would approximate total eradication costs in the fifth year (1977), having a positive balance in the sixth and subsequent years.

It is possible that program costs would be lower due to smaller areas that would need to be treated or areas where eradication is achieved earlier, but these cannot be predicted in advance of a systematic, comprehensive trapping program and the monitoring program for the treatment areas. Thus, the total costs shown probably represent a maximum cost, rather than an average or minimum.