THE STERILE INSECT TECHNIQUE: COST-EFFECTIVE CONTROL OF THE MEDITERRANEAN FRUIT FLY

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Fruit flies are one of the most important plant pests of the world, in terms of the number of fly species involved, the regions in which they are present, and the variety of hosts they infest. Six main genuses are scattered all over the world. The A-B-Cs of fruit flies, in order of decreasing importance, are: *Anastrepha*, 183 species (spp.), 15 of economic importance (econ. imp.); *Bactrocera*, 486 spp., 39 of econ. imp.; and *Ceratitis*, 70 spp., 11 of econ. imp. Three other genuses round out the picture: *Dacus*, 235 spp., 11 of econ. imp.; *Rhagoletis* , 62 spp., 6 of econ. imp.; and *Toxotrypana*, 7 spp., 1 of econ. imp.

Anastrepha is present in the Americas; *Bactrocera* in Asia and *Ceratitis* in Africa; *Dacus* in Africa and South East Asia, Australia and South Pacific Islands; and *Rhagoletis* in Chile, Peru, Eastern and Western USA, Europe and Asia (from Sweden to Kyrgystan and from Russia to France). There is an important species of *Bactrocera*, the Olive Fruit Fly (*B.oleae*), present in all olive-growing regions of Africa, Europe, the Middle East and Arab countries.

Seventy five species of plants of economic importance are infested by fruit flies. Among them are tropical fruits such mango, guava, banana, papaya, fig, passion fruit and avocado; temperate fruits such as citrus (orange, grapefruit, tangerine, etc.), stone fruits (peach, apricot, cherry, etc.), nuts, grape, apple and pear; and vegetable crops such as cucurbits (squash, melon, watermelon), tomato, and eggplant. Fruit flies are present in 178 countries and islands; they are ubiquitous throughout the world between 45° North and 45° South latitude.

Twenty species of fruit flies are the most harmful because of the range of hosts they infest and the many countries affected. These 20 are subject to quarantine: trade in fresh produce is restricted to avoid the introduction of any one of these species.

The Mediterranean Fruit Fly, or simply Med Fly, (*Ceratitis capitata* Weid.) is the most harmful of all. It is present in 77 countries and infests 22 hosts of economic importance. From its origin in Central Africa, it has invaded northern Africa, Mediterranean Europe, the Middle East, all the Americas, and Australia. All the countries affected devote major efforts to eradicate this pest or greatly reduce its prevalence. The Med Fly has been eradicated from the USA (except Hawaii), Mexico, and Chile. Nevertheless, ongoing re-introductions occur and must be dealt with in Florida and California, Mexico and Chile.

Fruit flies, like any other pest, have been attacked with biocides at the farm level. Citrus is an instructive example. Citrus flowers and fruits twice a year, and various species and varieties provide year-round harvests. Biocides are typically applied to citrus every 10-15 days. Even so, the effectiveness is usually only 70-80%, due to uncontrolled neighboring farms, untreated hosts, problems with the spraying equipment, dose miscalculations, etc. Aerial applications of bait sprays to wider areas are more expensive, require a regional plan, and can represent a major impact to the environment. All means of application can leave pesticide residues in the fruit.

Trade in fresh fruits and vegetables is being liberalized on a world-wide basis as part of globalization. At the same time, local consumption of fresh products is increasing in the search for a healthier life. Pesticides are increasingly less acceptable in both the export trade and local markets. Newly adopted food safety and phytosanitary standards require the establishment of either low prevalence or entirely fruit fly-free areas. Environmental considerations reinforce the already favorable cost-benefit picture for the Sterile Insect Technique (SIT) as an alternative to controls that use chemicals alone.

The SIT has been in use since the 1950s. The aim of the technique is to disrupt the life cycle of the fly, mating the wild population with sterile flies reared at a "fly factory". Sterilization is accomplished by exposing insects to a specific dose of gamma radiation emitted by radioisotopes (cobalt-60 or cesium-137). Irradiation is a central and indispensable part of the total SIT process: every insect among millions produced each week must to be sterilized. No other method is available to achieve sterilization; chemosterilants, linear accelerators and the like have proven less cost-effective.

However, SIT is not a stand-alone technology. It is a valuable tool, but not the whole answer. To be effective, it must be integrated into a package together with non-nuclear techniques. These include a trapping system;

fly population monitoring; fruit sampling; laboratory analyses; data gathering and processing; mass rearing facilities; proper sterile fly handling and packing; aerial and/or terrestrial release protocols; cultural and chemical control of wild populations; quarantine protection; economic analyses; and public education.

Programs of fruit fly eradication and/or control using SIT are under way in California, Florida, Mexico, Central America, Peru, Chile, Argentina, Madeira, Israel, Jordan, South Africa, Thailand, Japan, Australia, and the Philippines. The majority target Medfly, with 21 labs and medium to large mass rearing facilities worldwide. But SIT is also being used against other fruit flies of economic importance including *A. ludens, A. obliqua, A. serpentina, A. suspensa, B. cucurbitae, B. Philippinensis,* and *B. tryoni*, involving facilities with production capacities from 11 to 100 million flies/week. Laboratory-scale rearing operations (less than 10 million/week), exist for *A. fraterculus, B. dorsalis, B. latifrons, B. oleae, B. zonata*, and *C. rosa*.

There is no doubt that the cost-benefit ratio favors SIT. Data from Argentina, the Middle East, California and Thailand illustrate this point. Costs are smaller than for chemical treatment, even if one disregards the hidden factors that the SIT affects only the target pest; does not disrupt beneficial fauna and bees; and can have a favorable impact on the environment. In California, for example, the Preventive Release Program (PRP) in the Los Angeles area releases 450 million sterile flies a week over an area of 2,489 sq-miles. A permanent Medfly infestation would provoke an estimated loss of 1,333 - 1,863 million US$, due to increased pesticide use, quarantine compliance costs, increased costs of production and trade embargo, plus the environmental impact of increased pesticide use estimated at between 280,000 to 5,000,000 pounds annually. The average number of Medfly infestations in Los Angeles was 7.5/year before the PRP started (1987-94). This figure dropped to an average of 0.15/year after the PRP began, while annual control costs fell from US$ 30 million before PRP to US$ 14 million afterwards.

In Argentina, the total cost of the Medfly Program in Mendoza for the 2000-01 campaign is US$ 5.5 million. Fly traps cover some 546,000 ha, which gives a direct cost of 10.07 US$/ha. If we consider the actual area of 160,000 ha over which sterile flies are released, the cost increases to 34.36 US$/ha. For comparison, in the major citrus growing area of Argentina, chemical applications consist of a bait of 5% sugar cane syrup (food), 3% nulure (attractant), and 0.1% malathion (insecticide). Applications are done on a weekly basis, with a mean of 12 applications per citrus variety over a period of 3 months. Varieties of orange, grapefruit and tangerine are grown all year round in a permanent rotation schedule. Direct costs of chemical applications--- including bait, labor , other inputs, and lease of machinery--- sum to US$ 10-20/ha per application. The total cost for each variety reaches US$ 120-240/ha.

A study in Israel and Jordan evaluated three alternatives: conventional malathion aerial bait spraying (C), the most common practice; SIT for eradication (E); and SIT for control (CO). Over a period of 14 years, annual costs were as follows. At year 3: C = US$ 60 million, E = $ 40 million and CO = $ 40 million, respectively; at year 4: $ 60, 30, and 70 million; and from years 8 to 14: $ 60, 25 and 10 million.

The application of SIT for control rather than eradication sees the sterile fly as a biological insecticide. SIT is used in this way by the PRP in Los Angeles. It is applicable to area-wide control in many important fruit growing areas of the world. At a consultants meeting in Vienna in November, 1999, the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture promulgated three such projects. One covers the citrus and tropical fruit growing regions of Mexico, Central America and Panama; it is now under way. A second project targets the world's largest citrus growing area, the Mercosur countries of South America. The third project focuses on the Mediterranean Basin (Southern Europe, Northern Africa and the Middle East), the second largest citrus growing region of the world.

The main objective of international organizations like FAO/IAEA should be to develop projects on a regional basis in order to meet the requirements of the area-wide concept. For their part, Member States should apply for and implement this kind of project in validation of the advice of the international organizations.

TABLE 1: STATISTICS OF FRUIT FLIES OF THE WORLD

GENERA OF FRUIT FLIES.TOTALNUMBER OF SPECIES (TNS) AND NUMBER OF SPECIES OF ECONOMIC IMPORTANCE (EI)

GENERA	TNS	EI
Anastrepha spp	183	15
Bactrocera spp	486	39
Ceratitis spp	70	11
Dacus spp	235	11
Rhagoletis	62	6
Toxotrypana	7	1
TOTAL	**1,043**	**83**

MOST IMPORTANT SPECIES BY THE NUMBER OF HOSTS THEY INFEST

SPECIES	N°OF HOSTS
C.capitata	22
B.tryoni	11
B.dorsalis	9
B.cucurbitae	9
C.rosa	8
B.neohumeralis	8
A.fraterculus	8
B.zonata	7
A.suspensa	7

NUMBER OF FRUIT FLY SPECIES (NFFSP) ON THE SAME HOST

HOST	NFFSP
CITRUS	29
MANGO	29
GUAVA	24
PEACH	20
CUCURBITS	17
TROPICAL FRUITS	16
SQUASH	14
TOMATO	13
APPLE	12
AVOCADO	12
CUCUMBER	12
PAPAYA	11

There are at more than 75 plant species of economic importance hosts of fruit flies. The list includes Tropical fruits, pome fruits, stone fruits, grape, nuts, cucurbits, solanaceae, etc.

GEOGRAPHICAL DISPERSION OF FRUIT FLIES

SPECIES	N°COUNTRIES
C.capitata	77
A.obliqua	35
C.cucurbitae	28
B.oleae	27
D.ciliatus	25
A.fraterculus	22
R.cerasi	22
D.vertebratus	21
C. rosa	17
A.serpentina	16
A.striata	15
C.punctata	15

COUNTRIES WITH THE MOST IMPORTANT BIODIVERSITY (NATURAL AND / OR INTRODUCED) OF FRUIT FLIES OF ECONOMIC IMPORTANCE OVER 6 GENERA AND 83 SPECIES

COUNTRY	N° SPECIES
BRAZIL	14
INDONESIA	13
SOUTH AFRICA	13
THAILAND	13
ZIMBABWE	13
KENYA	12
TANZANIA	12
AUSTRALIA	10
INDIA	10
PAPAUA/NEW GUINEA	10
PERU	10
VENEZUELA	10

Source:

THOMPSON, F. C. 1998. Fruit Fly Expert Identification System and Systematic Information Database.: A resource for identification of fruit flies and maggots, with information on their classification, distribution and documentation.

USDA. 1999. Fruit Fly Cooperative Control Program. Draft Environmental Impact Satement.

WHITE, I . M. and M. M .ELSON-HARRIS. 1992. Fruit Flies of Economic Significance: Their identification and bionomics.

TABLE 2: LABS AND MASS REARING FACILITIES OF THE WORLD BY SPECIES

COUNTRY	LOCATION	OPERATING SINCE	SPECIES	STRAIN	PRODUCTION MILIONS/WEEK	TOTAL MALE
PERU	PIURA	1999	A.fraterculus		1 to 2	
MEXICO	METAPA	1994	A.ludens		200-250	
USA	TEXAS	1986	A.ludens		18-40	
COSTA RICA	SAN JOSE	1960's	A.obliqua		less 1	
MEXICO	METAPA	1994	A.obliqua		50	
USA	TEXAS	1992	A.obliqua		less 1	
MEXICO	METAPA	1994	A.serpentina		5 to 10	
USA	TEXAS	1992	A.serpentina		less 1	
USA	FLORIDA	1987	A.suspensa		20-50	
JAPAN	OKINAWA	1973	B.cucurbitae		50-100	
USA	HAWAII	1956	B.cucurbitae		3	
THAILAND	PATHUMATANEE	1987	B.dorsalis		10	
USA	HAWAII	1956	B.dorsalis		1 to 5	
USA	HAWAII	1984-90	B.latifrons		less 1	
GREECE	ATENAS	1970's	B.olea		less 1	
PHILLIPINES	MANILA	1980's	B.philippinensis		1 to 20	
AUSTRALIA	PERTH	1989-90	B.tryoni	Bisexual	40	
AUSTRALIA	CAMPDEN	1996	B.tryoni	Bisexual	20	
PAKISTAN	TANDOJAM	1980's	B.zonata		1 to 3	
ARGENTINA	SAN JUAN	1982	C.capitata	Bisexual. San Juan	5 to 15	
ARGENTINA	MENDOZA	1992	C.capitata	SEIB 6 96	300	140
AUSTRALIA	PERTH	1978-85	C.capitata	Bisexual PERCVQ	10 to 15	
AUSTRALIA	PERTH	1999	C.capitata	VIENNA 7 99		10
AUSTRIA	SEIBERSDORF	1960's	C.capitata	Strain Collection	5 to 10	
BRAZIL	PIRACICABA	1997	C.capitata	Bisexual normal	less 1	
CHILE	ARICA	1993	C.capitata	SEIB 9 96		45
COSTA RICA	SAN JOSE	1960's	C.capitata	Bisexual local	5 to 10	
GREECE	CRETA	1993	C.capitata	SEIB 6 98/VIENNA 7 99	1 to 2/ 9	
GUATEMALA	PETAPA	1984	C.capitata	Bisexual Antigua	300-400	
GUATEMALA	EL PINO	1996	C.capitata	Bisexual Petapa/Antigua	200	
GUATEMALA	EL PINO	1996	C.capitata	VIENNA 4 94 TOLIMAN		450
GUATEMALA	EL PINO	1997	C.capitata	VIENNA 7 97		450
LEBANON	BEIRUT	1999	C.capitata	VIENNA 4 94 TOLIMAN		3
MEXICO	METAPA	1979	C.capitata	Bisexual Guatemala	400 - 500	
PERU	LA MOLINA	1960's	C.capitata	VIENNA 7 97		120
PORTUGAL	MADEIRA	1994	C.capitata	VIENNA 6 96		40
SOUTH AFRICA	STELLENBOSCH	1999	C.capitata	VIENNA 7 99		10
USA	HAWAII USDA	1991	C.capitata	Bisexual MAUI	200 - 300	
USA	HAWAII CDFA	1970's	C.capitata	Bisexual HILAB	70-150	
USA	HAWAII CDFA	1997-99	C.capitata	Bisexual HILAB	200 -300	
SOUTH AFRICA	STELLENBOSCH	1990's	C.rosa		1 to 3	

Source: Thematic Plan for Fruit Fly Control Using the Sterile Insect Technique. IAEA. Vienna. Austria. November 1999

TABLE 3: MOST IMPORTANT FRUIT FLIES FOR THE NUMBER OF HOSTS THEY INFEST; THE NUMBER OF COUNTRIES THEY ARE PRESENT IN AND/OR THERE IS A SIT TECHNIQUE

COMMON NAMES OF FRUIT FLIES (FF)	SCIENTIFIC NAMES OF FRUIT FLIES	TOTAL N° HOSTS	TOTAL N° COUNTRIES	MASS REARING FACILITIES			TOTAL FACILITIES
				LABS	11-100	MORE 100	
South American FF	A.fraterculus	8	22	1			1
Mexican FF	A.ludens	5	8		1	1	2
West Indies FF	A.obliqua	5	35	2	1		3
Sapote FF	A.serpentina	4	16	1	1		2
Guava FF	A.striata	5	21				0
Caribbean FF	A.suspensa	7	7		1		1
Oriental Melon FF	B.cucurbitae	9	28	1	1		2
Oriental FF	B.dorsalis	9	7	2			2
Solanum FF	B.latifrons	3	8	1			1
	B.neohumeralis	8	2				0
Olive FF	B.oleae	1	27	1			1
	B.philippinensis	3	1		1		1
Queensland FF	B.tryoni	11	1		2		2
Peach FF	B.zonata	7	7	1			1
Mediterranean FF	C.capitata	22	77	7	4	10	21
	C.punctata	2	15				0
Natal FF	C.rosa	8	17	1			1
Ethiopian FF	D.ciliatus	4	25				0
	D.vertebratus	4	21				
European Cherry FF	R.cerasi	1	22				0
	TOTAL	**126**	**367**	**17**	**13**	**11**	**41**

Note: Labs are those which produce less than 10 million flies a week; Medium between 11 and 100 million; Large more than 100 million flies/week