Fruit fly control and monitoring in the Near East: shared concern in a regional transboundary problem

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The Mediterranean fruit fly, Ceratitis capitata (Wiedemann), is a pest of major economic significance in most of the temperate, subtropical and tropical countries. In 1997, a pilot project named the Arava Medfly Eradication Project (AMEP), was initiated in the Arava Valley region south of the Dead Sea in Israel to control Medfly populations using the sterile insect technique (SIT) and thus allow export of commodities from the region to the U.S.A. and Japan without expensive post-harvest treatments. In 1998, the Hashemite Kingdom of Jordan joined the AMEP and launched a project in the Araba, the Jordanian side of the Arava Valley region. From 1998, sterile males of a temperature sensitive lethal (tsl) strain of Mediterranean fruit fly originating first from Madeira-Med facility then later from the Guatemalan El Pino facility, were released weekly over the Arava/Araba region. From 1999, the Territories Under the Jurisdiction of the Palestinian Authority (TUJPA) joined the regional effort and initiated Medfly monitoring operations in the Gaza Strip. In early 2001, the project was extended to the Western Negev region of Israel. Weekly, 15 million sterile tsl males of strain Vienna 4-Tol 94 from Guatemala and five million sterile tsl males of strain Vienna 7i/Mix-2001 from the IAEA Laboratories in Seibersdorf, Austria, are shipped and released over the Arava/Araba valley and the Western Negev. Despite some technical problems due to long-duration shipment of pupae from Guatemala, and to the lack of quarantine restrictions in the Arava/Araba, the Medfly population has been successfully suppressed on both sides of the Jordan River south of the Dead Sea. In 2000, as a result of the Medfly suppression effort, the area from which Israeli Arava producers have been able to export vegetables certified ‘free of Medfly’ to the U.S.A., without post-harvest treatment, has been expanded. On the basis of the success in the Araba, Jordan is considering the use of area-wide SIT to suppress Medfly in the commercial fruit- and vegetable-growing area of the Shuna Valley, between north of the Dead Sea and the Sea of Galilee. Based on the experience gained by its neighbours and on data accumulated during monitoring, sterile male releases are expected to be initiated in 2003 in the Gaza Strip.

The peach fruit fly, Bactrocera zonata (Saunders), is a South-East Asian pest that is of major quarantine importance for exports to the U.S.A., Japan and European countries. In December 1998, this pest was officially identified and recorded for the first time in Egypt where it attacks some of the main fruit varieties in the Near East (e.g. mangos, peaches). In 2001, Egypt initiated a project to monitor and control this pest in the Sinai, using the male annihilation technique (MAT). Presence of the pest has now been confirmed from all areas of the Sinai, throughout the Nile Delta region and the entire Nile Valley. The plant protection authorities of Israel, Jordan and the TUJPA established emergency detection trapping networks in the border areas of Egypt, suspended importation/ transit of Egyptian commodities, and are prepared to launch emergency plans. Area-wide MAT operations will soon be initiated in Eastern Sinai, progressing westwards towards the Suez Canal.

Current status and cooperation among the four projects regarding these two major fruit fly pests are presented and discussed.

INTRODUCTION

The Mediterranean fruit fly, Ceratitis capitata (Wiedemann), is a pest of major economic significance in most of the temperate, subtropical and tropical countries where it attacks over 300 wild and cultivated host plants (Liquido et al. 1991). The presence of Medfly in the Near East region was first recorded in 1904 (cited in Dridi 1990). Damage caused by the Medfly can be considered from various aspects. As a primary pest, Medfly can cause losses as high as 80–100% of a fruit crop in the region (Rössler et al. 2000). This situation is -
often encountered in the Hashemite Kingdom of Jordan (hereafter named Jordan) in backyards or orchards where no control methods are applied. Considering the damage caused by Medfly, conventional insecticides need to be applied several times a year, at high economic and environmental costs (Pimentel et al. 1992). In Israel, and to a lesser extent in the Territories Under the Jurisdiction of the Palestinian Authority (TUJPA), ground or aerial bait spray applications need to be made over 12 times a year in order to effectively guarantee production. In such cases, Medfly control precludes the use of biocontrol methods against secondary pests such as the citrus leafminer, Phyllocnistis citrella, and is thus responsible for increasing pesticide usage. This situation can be found in areas such as the TUJPA and in some areas of Israel. Finally, in some areas where no or only few major Medfly hosts are grown commercially, only the presence of Medfly, considered as a quarantine pest, precludes access to high value Medfly-free export markets such as the U.S.A. or Japan. This is the case in the Arava Valley south of Israel. Considering the common threat represented by the Medfly for Israel, Jordan and the TUJPA, three projects were launched that aim at controlling Medfly in various areas of the region. From 1999, the three projects started sharing knowledge and expertise, and various area-wide control strategies and objectives were established according to the specific needs of each operational zone of this supra-national project.

The peach fruit fly, Bactrocera zonata (Saunders), is a South-East Asian pest that is of major quarantine importance for exports to U.S.A., Japan and European countries. This pest is known to occur in the Indian Ocean (Réunion and Mauritius) and in tropical Asia (India, Indonesia, Laos, Sri Lanka, Thailand and Vietnam) (White & Elson-Harris 1992). Some peach fruit fly detections occurred in 1998 in the U.S.A. in Orange and Contra Costa Counties of California (CDFA 1998a,b). Additional detections occurred in Santa Clara and Riverside Counties in 2001. Infestations resulting from these introductions were eradicated using the male annihilation technique (MAT) (Dowell, pers. comm.). In December 1998, this pest was officially identified and recorded for the first time from Egypt (Taher 1998) where it attacks over 50 known host plants, including some of the main fruit varieties grown in the Near East (e.g. mangos, peaches, apricots, citrus) (FAO/IAEA 2000). In 2000, the peach fruit fly was first recorded on the border between the TUJPA and Israel (NAPPO 2001a,b). In 2001, a project was launched in Egypt to monitor and eradicate this pest from the Sinai. Considering the common threat that the peach fruit fly represents for export markets of Israel, Jordan, the TUJPA and Egypt, national representatives decided to address this issue at a supra-national level by sharing monitoring information, regional training and knowledge of control methods.

In the present document, the current status and cooperation among the four projects regarding these two major fruit fly pests are presented and discussed.

FRUIT FLY CONTROL IN THE NEAR EAST: A HISTORICAL PERSPECTIVE

The control of Medfly in the Near East has a long history. As early as 1958, a centralized control programme for Medfly was set-up in Israel (Rössler 1987). This programme was based on weekly monitoring of trimedlure-baited traps, use of aerial photography and aerial application of malathion bait sprays. This programme, slightly adapted to include new technologies (use of GIS) remained largely unchanged and it is still currently used by the Citrus Marketing Board of Israel to control Medfly in citrus production areas. In 1989/90 in Israel, a successful demonstration of the effectiveness of the sterile insect technique (SIT) to control Medfly was carried out in a 500-ha area in kibbutz Gvulot in Northern Negev (Nitzan et al. 1993).

In 1993/94, the Oslo agreements between the State of Israel and the Palestinian Liberation Organization, and the peace treaty between Israel and Jordan laid the groundwork for the development of regional cooperation. In 1994, a panel of experts evaluated the potential of using SIT to control and/or eradicate Medfly in the Near East region, including countries such as Cyprus, the Syrian Arab Republic, Lebanon, Israel, Jordan and the TUJPA (FAO/IAEA 1995). Considering that up to 12 pesticide applications were needed annually to protect 530 000 ha of fruit production valued at US$1.500 million per year (FAO/IAEA 1995), it was suggested that SIT would greatly reduce the amount of pesticide used in the region, resulting in a better, environmentally compatible and sustainable approach to Medfly control. The panel of experts concluded that an economic analysis of the cost/benefit of using various control methods was needed.

In 1995/96 an economic evaluation of three alternative methods (bait application technique (BAT) for suppression, SIT for suppression and SIT for eradication) for the control of Medfly in the Near
East was made. This study concerned Israel, Jordan, the TUJPA (Enkerlin & Mumford 1997), Lebanon and the Syrian Arab Republic (IAEA 2001). The evaluation revealed that, should no control be applied against Medfly, the annual fruit losses would amount to US$365 million for Israel, Jordan and the TUJPA (Enkerlin & Mumford 1997). Under the current control methods, the direct and indirect damage was estimated as high as US$192 million per year. Considering the economic impact of Medfly in the region, the use of SIT for suppression was considered cost-effective over a nine-year period, and the use of SIT for eradication appeared cost-effective over a longer period, although the latter was more problematic. The area-wide bait suppression strategy was not considered sustainable in the long term.

A feasibility study to eradicate Medfly from the Arava Valley, South of the Dead Sea was launched in 1997 (Rössler et al. 2000) with the technical and financial support of the International Atomic Energy Agency (IAEA). During the same year, Jordan joined the regional effort with the aim of eradicating Medfly from the Araba Valley, the Jordanian side of the Arava Valley. Aerial releases of sterile Medfly males were initiated in late 1997 and are continuing.

In 1999, building upon the regional expertise gained in the region, the TUJPA embarked on a Medfly control project and started benefiting from regional training and visits by fruit fly experts. In 2001, Israel, Jordan and the TUJPA were awarded a US$2.5 million USAID grant to promote the Middle East Regional Cooperation (MERC). Aerial releases of Medfly in Israel were extended to the Western Negev area. With the technical and financial support of the IAEA, Egypt launched a project to eradicate peach fruit fly in the Sinai Peninsula. In a regional effort to control the fruit fly species in the Near East, Egyptian representatives were invited to join the meeting of the national coordinators of the fruit fly projects and to share the knowledge and training made available to other countries in the region.

**DESCRIPTION OF THE PROJECT**

**Project area**

The project area has been defined as seven operational zones named: Arava Valley (I), Araba Valley (II), Jordan Valley (III), Western Negev (IV), Gaza Strip (V), Northern Negev (VI) and Hebron (VII). The implementation of the project in these zones is under the technical responsibility of Israel for zones I, IV and VI, of Jordan for zones II and III, and of the TUJPA for zones V and VII (Fig. 1). The entire project area spreads from the Aqaba Gulf of the Red Sea in the south to the Sea of Galilee in the north.
Strategies and objectives

Though the common overall objectives in the region are to achieve the area-wide control of Medfly, to eradicate peach fruit fly from Egyptian Sinai and to avoid its spread throughout the Near East countries, the strategy and the foreseen medium-term objectives vary for each of the operational zones. On the basis of the local economical interest, and of the technology and personnel available, the objectives and the relevant technical requirements have been designed specifically for each of the operational zones (Table 1).

Table 1. Objective and technical requirements for each operational zone of the fruit fly project in the Near East.

<table>
<thead>
<tr>
<th>Operational zone</th>
<th>Objective</th>
<th>Requirements</th>
<th>Potential SIT release area (hectares)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Arava Valley</td>
<td>Medfly eradication</td>
<td>Operational quarantine, Approved plan and materials ready</td>
<td>4 000</td>
</tr>
<tr>
<td>II Araba Valley</td>
<td>Medfly eradication</td>
<td>Operational quarantine, Approved plan and materials ready</td>
<td>4 000</td>
</tr>
<tr>
<td>III Jordan Valley</td>
<td>Monitoring/mapping</td>
<td>GIS based</td>
<td>20 000</td>
</tr>
<tr>
<td>IV Western Negev</td>
<td>Monitoring/mapping</td>
<td>GIS based</td>
<td>2 100</td>
</tr>
<tr>
<td>V Gaza Strip</td>
<td>Monitoring/mapping</td>
<td>GIS based</td>
<td>20 000</td>
</tr>
<tr>
<td>VI Northern Negev</td>
<td>Monitoring/mapping</td>
<td>GIS based</td>
<td>40 000</td>
</tr>
<tr>
<td>VII Hebron</td>
<td>Monitoring/mapping</td>
<td>GIS based</td>
<td>8 000</td>
</tr>
<tr>
<td>VIII Egyptian Sinai**</td>
<td>Monitoring/mapping</td>
<td>GIS based</td>
<td>33 000</td>
</tr>
</tbody>
</table>

*Potential area that could be under SIT operations for Medfly control.
**Though Egypt is not part of the projects funded by USAID, zone VIII has been added to illustrate actions needed to control peach fruit fly.

Project implementation and management

Each of the three projects is implemented at a national level with regional or local teams in charge of the field activities in each of the operational zones.

In Israel, the operations in the Arava Valley and in the Western Negev are implemented by the personnel of the Arava Medfly Eradication Project, under the supervision of the Plant Protection and Inspection Services (PPIS) of the Ministry of Agriculture and the Israel Cohen Institute for Biological Control of the Citrus Marketing Board of Israel (CMBI). A National Medfly Committee, chaired by the Head of the PPIS, reviews the activities related to Medfly undertaken under the project. Activities related to peach fruit fly are strictly under the supervision of the PPIS.

In Jordan, the field operations are implemented by the regional agriculture services in the Araba Valley and in the Jordan Valley, under the supervision of the Plant Protection Services of the Ministry of Agriculture in close cooperation with the Jordan...
of the flies (Prokopy mode of action, such as the behavioural responses 1952; Rössler 1989). Since then, some aspects of its Bactrocera dorsalis used in the 1950s against the oriental fruit fly, agent, called bait application technique (BAT), was CONTROL AND MONITORING METHODS

National coordinators of each of the four projects (including Egypt) meet once a year to review the technical progress achieved, review the work plans for the coming year, and decide on joint operations (training, field activities) to be carried out, with the technical support of the IAEA.

A Management Committee for the use of the USAID-MERC funds was established. This Management Committee meets twice a year and is composed of representatives of Israel, Jordan, the TUJPA and the IAEA. The Management Committee endorses the work plans defined by the national coordinators, assesses the appropriate use of funds, and decides on the long-term objectives of the regional project.

CONTROL AND MONITORING METHODS

Bait application technique

The application of a mixture of protein and killing agent, called bait application technique (BAT), was used in the 1950s against the oriental fruit fly, Bactrocera dorsalis (Hendel), in Hawaii (Steiner 1952; Rössler 1989). Since then, some aspects of its mode of action, such as the behavioural responses of the flies (Prokopy et al. 1992), or new formulations, such as the use of photoactive dyes as killing agent (McQuate & Peck 2000; Mangan & Moreno 2001), or new insecticides, such as Spinosad (Wood & Hardin 2000), have been studied.

In Israel, Medfly populations are successfully maintained below the economic threshold through the use of aerial BAT over citrus crops by the Citrus Marketing Board in collaboration with the Ministry of Agriculture (Rössler & Chen 1994). However, this method is not used in the Arava Valley or in the Western Negev (zones I and IV). In particular in zone I, where mainly organic products are grown, aerial bait sprays cannot be used; BAT is therefore applied from the ground, when needed, to control emerging populations in some Medfly hotspots and away from areas of commercial crops.

In the TUJPA, a centralized BAT programme is currently used by the Ministry of Agriculture, applied from the ground, but strictly limited to the citrus orchards during the fruiting season. The main objective of the fruit fly project for the Gaza Strip (zone V) in the coming years is to set up a centralized area-wide bait spray programme to suppress and not eradicate Medfly (Table 1).

In Jordan, BAT is also used in ground applications on a smaller scale to control Medfly hotspots in the Arava Valley (zone II) and especially to control Medfly in backyards on private properties in Aqaba City. In this case, 200–300 ml per tree (15–20 l/ha) the mixture (1% malathion technical formulation; 4% protein hydrolysate; 95% water) is applied at 7–10-day intervals for 30–40 days. As a first step in the Jordan Valley (zone III), it is foreseen to establish, through the coordinated efforts of the local fruit growers, a centralized area-wide bait spray programme to suppress and not eradicate Medfly.

Sterile insect technique

The sterile insect technique developed in the 1950s (Knipling 1955) has since been successfully used for many key pests worldwide (Krafsur 1998). One of the main limiting factors faced by SIT projects in the Near East is the lack of a Medfly mass-rearing facility in the region.

Previous SIT projects in the Near East have been among the first to use a Medfly genetic sexing strain (GSS) at an operational level (Franz et al. 1996; Robinson et al. 1999), and to benefit from the increased effectiveness of male-only releases (Hendrichs et al. 1995). From December 1997 until July 1998, two and then four million sterile pupae of the GSS Vienna 6-96 strain were received weekly from the Madeira-Med facility in Portugal (Pereira 1999) and released over zone I. From July 1998 until the present, an average of 12–13 million male pupae (of the GSS Vienna4/Tol-94, and as of 2000 of the Vienna 7/Tol-2000 strain) were shipped weekly (in two batches) from the El-Pino MOSCAMED rearing facility in Guatemala and released over zones I and II (Rössler et al. 2000). From 2001, an average of two million sterile male pupae have been released once a week over the Western Negev (zone IV). In August 2002, as part of the R&D activities of Medfly SIT programme, field-cage mating compatibility tests of a new GSS developed by the IAEA, Vienna 7D53/Mix-2001, were arranged in Israel with the cooperation of the Israel Cohen Institute and the IAEA. Two trial shipments were made from Austria and tests were run according to the International Standards described in the FAO/IAEA/USDA Manual (FAO/IAEA/USDA 2002). Local wild flies were obtained as pupae from Valencia oranges collected in Ma‘abarot, Israel. The mating compatibility of sterile males with wild females from Israel and the relative competitiveness of those males...
with wild males were measured and the results (Table 2) show that the two populations are sexually compatible.

No significant difference could be found between the mating competitiveness of the Vienna 7i/Mix-2001 and the wild males as shown by the relative sterility index (RSI) (McInnis et al. 1996) value (Table 2). Additional critical information, such as the time of calling (a prerequisite male behaviour to attract female mates), and the duration of mating, confirms that there is no behavioural incompatibility between the two populations. On that basis, it was concluded that sterile males from the V-7D53/Mix-2001 strain were competitive in copulation with and insemination of the wild females in Israel. Based on these positive results, from December 2002 an additional six million pupae of Vienna 7D53/Mix-2001 are shipped weekly from the IAEA rearing unit in Austria. These additional sterile flies are released over zones I and IV. Some of the major Quality Control (QC) data obtained for the three sources of pupae are presented in Table 3.

Even though the MOSCAMED facility is the furthest source of sterile pupae, it compares favourably with the two other sources (Table 3). For reasons due mostly to the size of the facility (to date over one billion sterile male pupae per week), MOSCAMED authorities can ship selected first-quality pupae (i.e. first-collection pupae), which under small capacity rearing conditions is nearly impossible, at a reasonable cost. The higher shipping

### Table 2. Mating compatibility in field-cage mating compatibility tests of the Vienna 7D53/Mix-2001 genetic sexing strain and a wild Medfly population from Israel (Gazit & Rössler, unpubl. data).

<table>
<thead>
<tr>
<th>Control</th>
<th>V-7D53/Mix-2001</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Both shipments</td>
</tr>
<tr>
<td>Proportion of mating*</td>
<td>0.46 aA**</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.15</td>
</tr>
<tr>
<td>(n = 6)</td>
<td>(n = 24)</td>
</tr>
<tr>
<td>Relative sterility index (RSI)</td>
<td>0.49 bB</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.13</td>
</tr>
<tr>
<td>(n = 6)</td>
<td>(n = 24)</td>
</tr>
</tbody>
</table>

*FAO/IAEA/USDA (2003). **Means with the same letter in the same row do not differ significantly according to the Tukey-Kramer HDS test at P = 0.05; n = number of replicates.

### Table 3. Comparison of quality control data obtained in Israel from shipments of sterile Medfly pupae from Madeira (Vienna 6-96), Guatemala (Vienna 4/Tol-94 and Vienna 7/Tol-2000) and Austria (Vienna 7i/Mix-2001) (after Rössler et al. 2000 and Rössler, unpubl. data).

<table>
<thead>
<tr>
<th>Origin of pupal shipment*</th>
<th>Madeira</th>
<th>Guatemala</th>
<th>Austria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypoxia duration (h)</td>
<td>44.88 ± 6.06</td>
<td>54.30 ± 9.44</td>
<td>45.33 ± 2.84</td>
</tr>
<tr>
<td>(n = 50)</td>
<td>(n = 307)</td>
<td>(n = 10)</td>
<td></td>
</tr>
<tr>
<td>White pupae (%)</td>
<td>9.28 ± 2.87</td>
<td>0.15 ± 0.21</td>
<td>0.00 ± 0.00</td>
</tr>
<tr>
<td>(n = 51)</td>
<td>(n = 300)</td>
<td>(n = 10)</td>
<td></td>
</tr>
<tr>
<td>Pupal weight (mg)</td>
<td>7.92 ± 0.34</td>
<td>7.70 ± 0.34</td>
<td>8.34 ± 0.17</td>
</tr>
<tr>
<td>(n = 54)</td>
<td>(n = 303)</td>
<td>(n = 10)</td>
<td></td>
</tr>
<tr>
<td>Emergence (%)</td>
<td>60.77 ± 9.07**</td>
<td>73.62 ± 9.46</td>
<td>59.75 ± 5.56</td>
</tr>
<tr>
<td>(n = 51)</td>
<td>(n = 298)</td>
<td>(n = 10)</td>
<td></td>
</tr>
<tr>
<td>Flying males (%)***</td>
<td>61.70 ± 9.34</td>
<td>64.32 ± 11.59</td>
<td>47.67 ± 7.07</td>
</tr>
<tr>
<td>(n = 50)</td>
<td>(n = 300)</td>
<td>(n = 10)</td>
<td></td>
</tr>
<tr>
<td>Survival (%)</td>
<td>75.57 ± 20.82</td>
<td>79.93 ± 13.23</td>
<td>63.84 ± 11.52</td>
</tr>
<tr>
<td>(n = 51)</td>
<td>(n = 296)</td>
<td>(n = 10)</td>
<td></td>
</tr>
</tbody>
</table>

*Data are presented as mean ± standard deviation; n = number of replicates. **Emergence rate in grids. ***As percentage of the total number of pupae.
cost from Guatemala to Israel is compensated for by the lower cost of the product in Israel due to cheaper labour. Last but not least, security regulations are applied to shipments sent to Israel upon departure from Europe, which ‘artificially’ increases the duration of hypoxia and thus negatively affects the emergence rate of adults. Under such circumstances, the benefit of a closer source of pupae, limiting the duration of hypoxia, is lost (Table 3). However, since the events of September 11, 2001, 18 shipments out of 51 did not arrive in Israel from Guatemala due to re-routing or cancellation of flights. The shipments that arrived in Israel suffered an increased duration of hypoxia, up to 61.10 ± 10.40 hours (n = 39). These problems highlighted the lack of commercial alternative sources of sterile male Medfly GSS pupae which could supply operational projects on large scale and on a regular basis.

In order to process the sterile pupae, an ‘emergence and release’ center was built by the Israeli authorities in 1997 in the Sapir Center in the Arava Valley (Rössler et al. 2000). The center, operated by the AMEP, is capable of processing up to 20 million sterile male Medfly pupae per week (Ravins, AMEP, pers. comm.; Rössler et al. 2000). The Sapir Center serves the needs of zones I, II and IV where aerial releases, and sometimes supplementary ground releases take place. Upon reception of the pupal shipment and transfer to the Sapir Center, pupae are placed into PARC boxes (45 000 pupae per box) (see Pereira 1999), provided with agar-based food and maintained at 21–22°C for four days, after which they are knocked down in a cold room for transfer into the chilled box used in the release machine.

The project is equipped with a Brittny Islander aircraft fitted with a chilled Medfly adult release machine loaded with a release module with a capacity of four million Medfly adults. While in the release module the 3–4-day-old adult Medfly males are maintained at 4–5°C. The aircraft flies 300 metres above ground level at 200 km/h, releasing an average of 220 000 Medfly adults per minute. The flying and release operations take about four hours and takes place twice a week over the Arava/Araba Valley (zones I and II). AMEP is operating the release on behalf of the Jordanian authorities over the Arava Valley and for the Israeli project over the Arava Valley and the Western Negev. In zone I, releases cover 19 agricultural settlements and the city of Eilat, while in zone II, releases cover only three agricultural settlements and the city of Aqaba. The area represented by zones I and II is naturally isolated from other potentially Medfly-infested areas as described by Rössler et al. (2000). Aerial releases, which take place only once a week in the Western Negev, cover the area between Dimona and Nizzana.

SIT will be used to eradicate Medfly from zones I and II, once effective quarantine is set up to protect those two areas, and to suppress Medfly in zone IV.

**Male annihilation technique**

This method, first developed in the 1940s, has proved efficient against several species of *Bactrocera* worldwide (Cunningham 1989; Marwat et al. 1992). Among others, it is currently used to eradicate the Carambola fruit fly, *Bactrocera carambola* (Drew & Hancock), from the northern portions of South America where the pest was accidentally introduced in the 1970s (Malavasi et al. 2000) and against the peach fruit fly on Réunion Island (Jeuffrault et al. 2000). MAT is based on the attractiveness of the males to methyl-eugenol, a component of the male pheromone. *B. zonata* males are attracted from long distances to a source of methyl-eugenol on which they feed usually once only in their lifetime (Shelly 1997, 2000). MAT aims at distributing an absorbent substrate impregnated with a mixture of pesticide and methyl-eugenol (also called ‘lure & kill’ stations) in the targeted area. Only the males are attracted by the lure & kill stations, they feed on the mixture, ingest the insecticide and die. By effectively maintaining impregnated stations (500 km²) in the field in an area-wide manner during 40 consecutive weeks, the male population disappears, leaving the wild females without mates. Therefore, after such a period only residual infested areas (often limited to one tree), also called ‘hotspots’, may persist. These hotspots can then easily be treated by localized ground-applied bait sprays and/or cultural practices (fruit collection and destruction). The methyl-eugenol attracts specifically some species of *Bactrocera*, and thus has with very little, if any, impact on non-target insect species as demonstrated in Hawaii (Kido et al. 1996). Various types of lure & kill stations have been used worldwide. These bait stations are of two major types: stations made of material impregnated with a mixture of methyl-eugenol and killing agent (such as Malathion) (ratio 3:1), such as is used in Suriname against *B. carambola* (Malavasi et al. 2000), or spot applications of a thick gel (Min-U-Gel®) mixing methyl-eugenol and killing agent, such as used in California (Cunningham & Suda 1985). Blocks are hung preferably on host trees and are replaced every six weeks; spot Min-U-Gel® applications are
often used in cities and are applied on telephone poles or street signs. Min-U-Gel® treatments need to be reapplied every two weeks.

In Israel, in kibbutz Kerem Shalom where about 20 B. zonata males were captured in the last months of 2001, spot applications are done on each potential host tree every two weeks. Preventive MAT operations have been extended to the adjacent agricultural settlements along the Gaza Strip and Egyptian border.

In the Gaza Strip, preventive MAT operations were due to be launched in 2003/04, through the technical support of the Israeli PPIS.

In Egypt, it is anticipated that either locally-made or ready-to-use lure & kill stations will be used, such as the BactroMAT™ M-E blocks developed by Aventis CropScience Ltd.

**Trapping**

The number and type of traps currently used in the projects in 2001 are summarized in Table 4. During this period, traps were serviced weekly in zones I, III and IV, and tentatively twice a month in the other operational zones.

In Israel, Steiner traps baited with liquid trimedlure were used exclusively before the initiation of sterile releases (Rössler et al. 2000). In 1998 in zone I, Steiner traps were replaced by Jackson traps (Katsoyannos 1994) baited with trimedlure (liquid or as a silicone plug) which were found more convenient for evaluating the ratio of fertile:sterile males. This project was among the first worldwide to use Tephri® traps (Ros et al. 2000) baited with Biolure®, a registered formulation of putrescine + trimethylamine + ammonium acetate described and tested by Epsky et al. (1999) and Katsoyannos et al. (1999). This trap has proven extremely sensitive to low Medfly populations and for the capture of wild Medfly females. In areas under SIT operations, a few strategically placed Jackson traps are now used to confirm the efficiency of the sterile male releases, and Tephri® traps are used mainly to monitor the wild Medfly population. Steiner traps baited with liquid methyl-eugenol and Malathion are used to detect peach fruit fly.

In Jordan, Jackson traps baited with trimedlure plugs have been used in the Araba Valley since the early days of the project. A network of Jackson traps is being set-up in the Jordan Valley. In the Araba Valley, International Plastic Pheromone traps (IPMT) (Katsoyannos 1994) baited with Biolure® are used. In summer, water and surfactant are added to the traps. Jackson traps baited with liquid methyl-eugenol and Malathion are used to detect peach fruit fly.

In the TUJPA, Jackson traps baited with trimedlure replaced Steiner traps in 2001. Jackson traps baited with liquid methyl-eugenol and Malathion are used to detect peach fruit fly.

In the Egyptian Sinai, Jackson traps baited with liquid methyl-eugenol and Malathion have been set up to monitor peach fruit fly populations.

**Fruit sampling**

Fruit sampling has been done in the Arava Valley since 1997, as part of the routine operations of the project. Samples are held at the Sapir Center. From September 1997 until December 2001, 3503 fruit samples with a total weight of 1943 kg were collected. During this period an average of 67.37 ± 43.98 samples were collected monthly from 70 fruit varieties.

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**Table 4.** Numbers of each type of traps and lures in place in the fruit fly projects in the Near East in 2001.

<table>
<thead>
<tr>
<th>Type of trap (and lure)</th>
<th>Jackson (TML)</th>
<th>Tephri® (Biolure®)</th>
<th>IPMT (Biolure®)</th>
<th>Jackson (ME)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arava Valley (I)</td>
<td>121</td>
<td>350</td>
<td>0</td>
<td>*</td>
</tr>
<tr>
<td>Araba Valley (II)</td>
<td>32</td>
<td>0</td>
<td>100</td>
<td>20</td>
</tr>
<tr>
<td>Jordan Valley (III)</td>
<td>70</td>
<td>0</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Western Negev (IV)</td>
<td>57</td>
<td>88</td>
<td>0</td>
<td>*</td>
</tr>
<tr>
<td>Gaza Strip (V)</td>
<td>518**</td>
<td>0</td>
<td>0</td>
<td>80</td>
</tr>
<tr>
<td>Northern Negev (VI)**</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>*</td>
</tr>
<tr>
<td>Hebron (VII)</td>
<td>150</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Egyptian Sinai (VIII)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>638</td>
</tr>
</tbody>
</table>

* A total of 600 and 133 Jackson ME traps have been set up in Israel and in Jordan, respectively.

** One of these traps is located in the Israeli settlements of the Gaza Strip.

*** No activities related to the fruit fly project have yet been started in zone VI.
In the Western Negev, fruit sampling was initiated in July 1999. Until the end of 2001, a total of 179 fruit samples with a total weight of 140 kg were checked.

Fruit sampling has not yet been utilized on a sufficiently large scale in other operational zones of the project to be reported here.

RESULTS

The Arava Valley (zone I)

The Medfly population has been maintained under control in zone I, despite successive sterile pupae delivery failures and the absence of quarantine. When compared to data from 1997, fruit infestation in terms of number of pupae per kg of fruit sampled decreased (Fig. 2). However, the percentage of fruit samples infested was still as high as ~25%.

Assessing the data from a qualitative standpoint, Fig. 3 highlights the specific problem encountered in the Arava Valley. The settlements in the valley comprise agricultural fields with the ‘residential areas’ being totally separated from the commercial agricultural areas. While c. 85% of the agricultural activities in the valley take place inside greenhouses, Medfly host trees are planted in backyards where very little if any control can be applied. The data clearly show that while the fruit infestation rate decreased constantly in the orchards and open fields, it was relatively stable in residential areas after 1999.

Jackson TML trapping data (Fig. 4) confirms that sterile Medfly males were effectively distributed over the region, with over 20% of the traps capturing more than one sterile male per trap per day in 2001. The data also illustrate the effectiveness of the suppression operations, with 80% of the traps capturing less than 0.1 wild Medfly male per trap per day.
Data obtained from Tephri® Biolure® traps in 2001 (Fig. 5) confirmed the observation made with the Jackson TML traps. Tephri® traps are known to be more sensitive than Jackson traps in detecting low levels of Medfly populations, and they are mainly used for the early detection of wild females out of which a wild population can build up very rapidly. The data show that, during 2001, over 90% of the Tephri® traps caught less than 0.1 wild female per trap per day.

The relatively successful suppression of the wild Medfly population in the Arava Valley in 2001 was possible through the combination of cultural practices (collection of fruits in backyards), the relative support of the communities (especially in the moshavim) and the immediate response (ground bait sprays) to the lack of sterile pupae shipments from September to November. Further improvement in Medfly eradication activities was expected with the anticipated establishment in 2002 of internal quarantine to protect the Arava Valley.
The Araba Valley (zone II)

The Medfly control activities in the Araba Valley in 2001 were more affected by the lack of sterile pupae shipments from Guatemala from September to November than was the Arava Valley. The delay in applying alternative control actions resulted in wild Medfly populations building up in the second half of the year as shown in Jackson TML and IPMT Biolure® trapping data (Figs 6 & 7, respectively).

Unlike in the Arava Valley where agricultural settlements are spread along the entire valley, villages in the Araba Valley are concentrated in the northern part of the valley, where, consequently, Medfly populations are higher. The data (Figs 6 & 7) largely illustrate the situation encountered in villages such as El’Mazraa and Safi. Nevertheless, Medfly was kept under control in the large and populated city of Aqaba located at the southernmost tip of the valley (Figs 8 & 9).

The overall effectiveness (regardless of the type of flies captured) of the Jackson and IPMT traps in the Araba Valley is illustrated in Fig. 10.

In order to achieve successful control and later eradication of Medfly in the Araba Valley, cultural practices need to be improved. Communities in the area need to be better informed and involved in the project and effective quarantine measures should be implemented.

The Jordan Valley (zone III)

The Jordan Valley is the most important commercial fruit-producing area in Jordan, with, among others, over 5000 ha of citrus orchards. To date no centralized fruit fly control operations had been put in place, but a Jackson TML trapping network was initiated in September 2001. The initial
Fig. 8. Captures of wild (bars) and sterile (line) male Medflies in Jackson TML traps in Aqaba City (zone II) in 2001.

Fig. 9. Captures of wild male (grey bars) and wild female (white bars) medflies in IPMT Biolure® traps in Aqaba City (zone II) in 2001.

Fig. 10. Relative performance of IPMT Biolure® and Jackson TML traps in the Araba Valley in 2001.
trapping data (Fig. 11) showed that extremely high Medfly populations were present in this region (approximately 30% of the traps caught more than one wild Medfly male per trap per day).

On this basis, it is foreseen that the implementation of a centralized suppression programme (using BAT) will be needed before the use of SIT is considered. In 2002, training on area-wide fruit fly control methods was carried out in the area for the benefit of the fruit growers, and field operations were initiated.

**The Western Negev (zone IV)**

Pre-release operations were initiated in the Western Negev with fruit sampling from July 1999, and data have been compiled to October 2001. A total of 179 fruit samples were checked during this period. These samples contained 2651 fruits with a total weight of 140 kg. Out of these samples, 8215 Medfly pupae were collected from which 6080 Medfly adults emerged; 45.81% of these samples were infested. Eleven (57.89%) of the 19 settlements of the operational zone area contained infested fruits. Nizzana, the settlement bordering the Egyptian-Israeli border-crossing in Sinai, had the highest infestation rate, with 160 pupae/kg of collected fruits. The average infestation rate in the region is about 60 pupae/kg of collected fruits.

Sterile male releases over the Western Negev were only initiated in January 2001. Since then, about two million sterile male pupae were going to be released over the region by the AMEP. However, administrative restrictions in flight over the area limited releases to once a week on Fridays. In addition, considering that 2001 was the first year of releases over this operational zone, the project team gave priority to the Arava/Araba Valley, when sterile pupae shipments were not timeously received. Consequently, the Western Negev suffered from fewer shipments of sterile pupae than other zones in the project.

Trapping data (Figs 12 & 13) clearly illustrate the effect of the lack of consecutive sterile releases in July and in October and November (see sterile males in Fig. 12).

Even though the results should not be compared to those of the Arava/Araba Valley, where several years of releases have already occurred, the large wild Medfly population encountered in the Western Negev would require preliminary area-wide BAT operations or supplementary control methods to take place rather than relying solely on the use of SIT.

**The Gaza Strip (zone V)**

The main objective of the project in the Gaza Strip was to build up capacity for area-wide Medfly suppression operations.

Until July 2001, 200 modified Steiner TML traps serviced every 10 days were used as a Medfly-monitoring network. However, this trapping network monitored only citrus orchards. From August 2001, and following the recruitment of a field team by the project, 518 traps were set up (Table 4) and included backyards and non-commercial hosts. Only ground spraying of Malathion plus Buminal was used in an attempt to control Medfly in this area, with little success. During the period February to July 2001, 12 tons of Buminal and 1.5 tons of Malathion were applied over 7700 hectares. The

![Fig. 11. Percentage Jackson TML traps capturing different numbers of wild male Medflies per trap per day in the Jordan Valley from October to December 2001.](image-url)
main goals of the project in the coming years are to set up an area-wide, functional and centralized integrated pest management approach against Medfly based on BAT, and at a later stage on SIT, which would, in the long term, reduce the use of insecticide sprayed over the TUJPA, and to effectively control the Medfly population.

The peach fruit fly detection trapping network comprising 80 Jackson ME traps did not catch any peach fruit fly since it was set up during 2001. Preventive MAT operations were anticipated to take place in 2002 in the most exposed areas, south of the Gaza Strip, with the technical support of the Israeli authorities.

**The Hebron area (zone VII)**

One of the major goals of the project in this operational zone was to set up and service a Medfly monitoring network (Table 1). A Jackson TML trapping network was set-up in 2001 (Table 4) and data will be made available in the near future to decide on an area-wide control strategy to be applied against Medfly in the area.

**The Egyptian Sinai (zone VIII)**

To our knowledge, even though a Jackson ME trapping network has been established in the Egyptian Sinai (Table 4), no effective MAT operations have yet taken place.

On the basis of data collected in Kalubia Governorate in the Nile Delta region in 1998 (Hashem et al. 2001), extremely high populations of *B. zonata* could be expected in the Sinai region bordering operational zones I, IV and V.
CONCLUSIONS

As from 2000, growers in the Arava Valley, as a result of Medfly suppression efforts, have been able to export vegetables (mainly tomatoes and bell peppers) certified ‘free of Medfly’ to the U.S.A., without chemical post-harvest treatment. This export market, valued at US$5 million/year in 1999 (Hendrichs 2001), has been expanded to US$8 million in 2001 (Ravins, AMEP, pers. comm.). It has been estimated that the potential export market for the Arava Valley, should Medfly be eradicated, would be valued at US$100 million/year. This achievement has been made possible with the cooperation of the Jordanian project that took action to control Medfly in the Araba Valley, and thus avoid continuous invasion of a ‘cleaned’ area.

On the basis of the success and the experience gained in the Araba, Jordan is considering the use of area-wide SIT to suppress Medfly in the commercial fruit and vegetable-growing area of the Shuna Valley, between the North of the Dead Sea and the Sea of Galilee (part of zone III). Without cooperation with Israel, Jordan would not have had the emergence and release capacity to undertake SIT operations in the Araba Valley. Should Medfly be eradicated from the Araba Valley, production of Medfly-free commodities could then be promoted for export to foreign markets, as is the case for the Arava.

Based on the experience gained by participating in regional technical training and meetings and with financial contributions to this project, the TUJPA is building its capacity to establish an area-wide integrated fruit fly management programme. On the basis of the data collected over these years, the TUJPA will design the best strategy for fruit fly control with the objective of protecting its fruit and vegetable exports, and to decrease the amount of pesticide applied per year.

The participation of Egypt in the regional activities contributed by maintaining the awareness of its neighbours to the threat represented by peach fruit fly, and by learning about specific control methods available. However, there is scientific evidence that the *B. zonata* population encountered in Egypt is adapting its morphology to local conditions compared with the original population in South East Asia (Iwahashi & Routhier 2001). The lack of control action in Sinai would present a permanent threat for all the countries in the Near East and North African regions. Those countries would need to be permanently ready for emergency action to eradicate outbreaks, as the Israeli authorities did in Kerem Shalom in 2000 and 2001.

For these reasons, several countries in the region have already banned Egyptian commodities for import and transit.

With the increase in international trade, fruit and vegetable commodities can reach many places worldwide in a few hours, thus increasing the risk of spreading pests and diseases across continents. Pest and diseases ignore human political borders. After decades of small-scale local individual management, increasing the use of the area-wide approach to pest management is paving the way to the development of multi-national projects that address problems at a transboundary level. Among other examples, this approach has proven effective in eradicating the screwworm fly, *Cochliomyia hominivorax* (Diptera, Calliphoridae), from North and Central America (Baumhover 2001). After 44 years of continuous progress, this pest has been eradicated from nearly half a continent, extending from southern U.S.A. to Panama (Krafsur 1998). This transboundary approach also helped to maintain southern Mexico free of Medfly, through cooperation and action taken by Guatemala (Hendrichs et al. 1983; Villasenor et al. 2000).

The present work shows that, even though they are handled at national levels and share common funds, the projects illustrate the benefits and the possibility for regional cooperation, on technical aspects, in the field of agriculture in the Near East region.

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