Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Insect Pest Control Newsletter

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To Our Readers

The state-of-the-art Mediterranean fruit fly mass-rearing and irradiation facility with the capacity of producing one billion sterile males per week, inaugurated on 29 August 2021 in Metapa de Dominguez, Chiapas, Mexico (Photo, SENASICA).

A new sterile Mediterranean fruit fly mass-rearing facility was recently inaugurated by the Mexican President in Metapa de Dominguez, Chiapas, Mexico. The facility, is a nursery for flies, using the most advanced fruit fly production and sterilization techniques. It is the world's second largest fruit fly facility with a capacity to produce one billion sterile males per week. The new facility incorporates recent developments in design, such as glass ceilings and walls, to allow more natural light for the adult flies in the mother colony area, which results in increased sexual competitiveness of the males once released. It was built in the vicinity of a facility, set-up in 1977 under the MOSCAMED Programme, a tripartite international commission between Mexico, Guatemala and the United States.

The goal of the facility is to consolidate the current containment barrier at Mexico's border with Guatemala, and to eliminate Mediterranean fruit fly gradually from Guatemala, in line with MOSCAMED's long-term objectives. The new facility will be instrumental in keeping the country free of this invasive pest, protecting, and supporting sustained production and trade of fruit and vegetable commodities.

Since 2010, Mexico's National Fruit Fly Programme (PNMF), to which *MOSCAMED* belongs, has been an IAEA Collaborating Centre with the main goal to support the IAEA with assistance on the sterile insect technique (SIT) to countries in the region. It has now been redesignated as a Collaborating Centre for additional four years. Through this cooperation, hundreds of professionals from Latin America, the Caribbean and other regions in the world have been trained in the application of the SIT and supported the Joint FAO/IAEA Programme with research and development in advancing the technology.

The IAEA has also designated the *Insectarium de Bobo Dioulasso-Campagne d'Eradication de la Mouche Tsétsé et de la Trypanosomose (IBD-CETT)* in Burkina Faso, West Africa as an IAEA Collaborating Centre to develop the SIT for the management of tsetse fly populations, a vector that transmits diseases that are harmful to both humans and animals (sleeping sickness in humans and nagana in livestock). The IBD-CETT was inaugurated in February 2017 and is the largest tsetse fly mass-rearing facility in West Africa with a capacity of producing 300 000 sterile males per week. The IBD is instrumental in providing the sterile male tsetse flies for the SIT programme to create a tsetse free zone in the Niayes of Senegal.

With respect to field programmes, I would like to highlight the important advancements on piloting the implementation of the preventive SIT against Mediterranean fruit fly in pest free areas in Patagonia, Argentina, and in Chile. Both countries are adopting a preventive release strategy that has been in place in California and Florida (USA) since 1994. Sterile males are released in areas where outbreaks occurred inside the fruit fly free areas in the past (see more details later in this newsletter). This is the first time that this strategy is used outside of the USA.

Furthermore, Rafael Mariano Grossi, Director General of the IAEA, visited the ongoing mosquito pilot trial in Recife, Pernambuco, Brazil, where he participated in insect releases as part of an IAEA-supported programme to use the SIT to control *Aedes* mosquitoes in the neighbourhood of Brasilia Teimosa. The project is implemented by Moscamed Brasil and operates one of the first SIT facilities in the world to mass-rear and sterilize *Aedes aegypti* mosquitoes for release. Moscamed Brasil initiated this pilot project in October 2020, to demonstrate the feasibility of using the SIT to suppress *Ae. aegypti* populations, the main vector of chikungunya, dengue, and Zika. Recently the releases were increased to twice a week with immediate impact on the suppression of the wild insect population.

IAEA Director General Rafael Mariano Grossi attends the Sterile Insect Release Ceremony for Dengue Mosquito Control Release during his official visit to Brazil in July 2021 (Photo: D. Calma/IAEA).

The Insect Pest Control Subprogramme also participated virtually in a side event organized by the IAEA on 'Contribution of Nuclear Science and Technology to Climate Change Adaptation' at the United Nations Annual Conference on Climate Change (COP26). Participation included the presentation of an animated infographic on 'Using Nuclear Science to Control Pests' and a session on 'Management of Insect Pests – the Role of the Sterile Insect Technique'.

Finally, I am pleased to inform our readers that a new coordination research project (CRP) on 'Improve the Mass-Rearing of Lepidoptera Pests for SIT Programmes' was just approved and the submission of research contract and agreement proposals are open until 30 April 2022 (see announcement with details in this newsletter).

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Forthcoming Events (2022)

I. Research Coordination Meetings (RCMs) of FAO/IAEA Coordinated Research Projects (CRPs)

Second RCM on Mosquito Irradiation, Sterilization and Quality Control. 18–22 July 2022, Vienna, Austria.

First RCM on Improve the Mass-Rearing of Lepidoptera Pests for SIT Programmes. 5–9 September 2022, Vienna, Austria.

Fourth RCM on Integration of the SIT with Biocontrol for Greenhouse Insect Pest Management. 8–12 November 2022, Sydney, Australia.

Third RCM on Assessment of Simultaneous Application of SIT and MAT to Enhance *Bactrocera* Fruit Fly Management. 20–24 November 2022, Sydney, Australia.

II. Consultants and Expert Meetings

FAO/IAEA Consultancy Meeting on Mosquito Male Performance. 23–27 May 2022, Vienna, Austria.

FAO/IAEA Consultancy Meeting on Guideline on Transboundary Shipments of Sterile Insects. 13–17 June 2022, Vienna, Austria.

III. Other Meetings/Events

FAO/IAEA Regional Workshop on Challenges and Solutions in the Implementation of SIT based Technologies against *Aedes* Vectors (under Regional TC Project RAS5082), co-organized with the National Environment Agency, Singapore. 12–19 January 2022 (virtual).

FAO/IAEA Second Coordination Meeting on Enhancing Capacity for the Use of the Sterile Insect Technique as a Component of Mosquito Control Programmes (under Regional TC Project RLA5083). 1–3 February 2022 (virtual).

FAO/IAEA First Coordination Meeting on Enhancing Regional Capacity for the Implementation of the Sterile Insect Technique as a Component for Area-Wide Tsetse and Trypanosomosis Management (under Regional TC Project RAF5087). 7–11 March 2022, Vienna, Austria.

FAO/IAEA Regional Stakeholder Engagement Meeting to Achieve Early Support to Sterile Insect Technique Pilot Trials against *Aedes* Mosquitoes (under Regional TC Project RER5026). 4–6 April 2022, Bologna, Italy.

FAO/IAEA Regional Training Course on Vector Control Needs Assessment, co-organized with the World Health Organization Regional Office for Europe (under Regional TC Project RER5026). 9–13 May 2022, Limassol, Cyprus.

FAO/IAEA Workshop on Irradiation and Dosimetry. 14–15 July 2022, Vienna, Austria.

XXVI International Congress of Entomology. 17–22 July 2022, Helsinki, Finland.

11th International Symposium on Fruit Flies of Economic Importance. 14–18 November 2022, Sydney, Australia.

Past Events (2021)

I. Research Coordination Meetings (RCMs) of FAO/IAEA Coordinated Research Projects (CRPs)

Fourth RCM on Improved Field Performance of Sterile Male Lepidoptera to Ensure Success in SIT Programmes. 18–21 May 2021 (virtual).

First RCM on Mosquito Radiation, Sterilization and Quality Control. 31 May–4 June 2021 (virtual).

Third RCM on Integration of the SIT with Biocontrol for Greenhouse Insect Pest Management. 21–25 June 2021 (virtual).

Second RCM on Assessment of Simultaneous Application of SIT and MAT to Enhance *Bactrocera* Fruit Fly Management. 28 June–2 July 2021 (virtual).

Second RCM on Improvement of Colony Management in Insect Mass-rearing for SIT Applications. 30 August–3 September 2021 (virtual).

Second RCM on Generic Approach for the Development of Genetic Sexing Strains for SIT Applications. 18–22 October 2021, Vienna, Austria (hybrid).

First RCM on Improving SIT Fruit Fly Field Programmes. 1–5 November 2021 (virtual).

II. Consultants and Expert Meetings

FAO/IAEA Consultancy Meeting on Improving SIT Fruit Fly Field Programmes. 7–11 June 2021 (virtual).

FAO/IAEA Consultancy Meeting on Rearing of Lepidoptera for SIT Application. 8–12 November 2021 (virtual).

III. Other Meetings/Events

FAO/IAEA First Coordination Meeting on Enhancing the Capacity to Integrate Sterile Insect Technique in the Effective Management of Invasive *Aedes* Mosquitoes (under Regional TC Project RER5026). 15–19 February 2021 (virtual).

FAO/IAEA First Coordination Meeting on Enhancing Capacity for the Use of the Sterile Insect Technique as a Component of Mosquito Control Programmes (under Regional TC Project RLA5083). 22–24 February 2021 (virtual).

Fifteenth Session of the Commission on Phytosanitary Measures (CPM-15), International Plant Protection Convention, FAO. 16, 18 March and 1 April 2021 (virtual).

FAO/IAEA Second Regional Coordination Meeting on Strengthening Food Security Through Efficient Pest Management Schemes Implementing the Sterile Insect Technique as a Control Method (under Regional TC Project RLA5082). 7 April 2021 (virtual).

FAO/IAEA Second Regional Coordination Meeting on Strengthening the Regional Capacities in the Prevention and Progressive Control of Screwworm (under Regional TC Project RLA5075). 8 April 2021 (virtual).

FAO/IAEA Regional Workshop on State-of-the-Art Sterile Fruit Fly Shipping, Packing and Release Systems (under Regional TC Project RLA5082). 16 April 2021 (virtual).

FAO/IAEA Second Regional Coordination Meeting on Advancing and Expanding Area-Wide Integrated Management of Invasive Pests, Using Innovative Methodologies Including Atomic Energy Tools (under Regional TC Project RAS5090). 19 May 2021 (virtual).

FAO/IAEA Regional Training Course on SIT Components: 'Methods for Mass-Rearing and Irradiation of *Aedes* Mosquitoes' (Module I) (under Regional TC Project RLA5083). 15–18 June 2021 (virtual).

FAO/IAEA Regional Workshop on Phytosanitary Schemes to Enable Fruit Exports Under the Framework of the WTO and the SPS Agreement (under Regional TC Project RLA5082). 21 June–2 July 2021 (virtual).

FAO/IAEA Regional Workshop on MEDNIP Database (under Regional TC Project RAS5090). 26–28 July 2021 (virtual).

FAO/IAEA Regional Training Course on SIT Components: Mosquito Monitoring, Data Collection and Data Management (Module II) (under Regional TC Project RLA5083). 27–30 July 2021 (virtual).

FAO/IAEA Regional Workshop on Managing Fruit Fly Surveillance Networks Based on Risk Factors (under Regional TC Project RLA5082). 26 July–6 August 2021 (virtual).

FAO/IAEA Regional Workshop on Communication Strategies for the Use of the Sterile Insect Technique as a Component of Mosquito Control (under Regional TC Project RLA5083). 3–5 and 9–11 November 2021 (virtual).

FAO/IAEA Regional Training Course on Management and Statistical Analysis of Data Collected from Mark-Release-Recapture Studies for *Aedes* Mosquitoes in Preparation of SIT Pilot Trials (under Regional TC Project RER5026). 6–10 December 2021 (virtual).

Technical Cooperation Projects

The Insect Pest Control Subprogramme currently has technical responsibilities for the following technical cooperation projects that are managed by the IAEA's Department of Technical Cooperation. They can be classed under four major topics, namely:

- Biocontrol using radiation
- Human disease vectors
- Livestock pests
- Plant pests

Country	Project Number	Ongoing National Projects	Technical Officer
Bolivia	BOL5022	Reducing Fruit Fly Populations in Different Regions Introducing an Integrated Pest Management Approach Including the Use of the Sterile Insect Technique	Walther Enkerlin
Brazil	BRA5061	Using the Sterile Insect Technique to Apply a Local Strain in the Control of *Aedes aegypti* (Phase II)	Rui Cardoso Pereira
Burkina Faso	BKF5020	Strengthening the Insectarium to Create Agropastoral Areas Permanently Liberated from Tsetse Flies and Trypanosomiasis	Adly Abdalla
Cambodia	KAM5006	Implementing Fruit Fly Surveillance and Control Using Area-wide Integrated Pest Management	Daguang Lu
Chad	CHD5007	Contributing to the Eradication of *Glossina fuscipes fuscipes* to Improve Food and Nutritional Security	Chantel de Beer
Chile	CHI5051	Implementing Pilot Level of Sterile Insect Technique for Control of *Lobesia botrana* in Urban Areas	Walther Enkerlin
China	CPR5026	Applying the Sterile Insect Technique as Part of an Area-wide Integrated Pest Management Approach to Control Two Fruit Flies	Daguang Lu
Cuba	CUB5021	Demonstrating the Feasibility of the Sterile Insect Technique in the Control of Vectors and Pests	Rui Cardoso Pereira
Dominican Republic	DOM0006	Building and Strengthening the National Capacities and Providing General Support in Nuclear Science and Technology	Walther Enkerlin
Ecuador	ECU5031	Enhancing the Application of the Sterile Insect Technique as Part of an Integrated Pest Management Approach to Maintain and Expand Fruit Fly Low Prevalence and Free Areas	Walther Enkerlin
Ecuador	ECU5032	Building Capacity for Mass Rearing, Sterilization and Pilot Release of *Aedes aegypti* and *Philornis downsi* Males	Maylen Gómez Walther Enkerlin
Ethiopia	ETH5022	Enhancing Livestock and Crop Production through Consolidated and Sustainable Control of Tsetse and Trypanosomosis to Contribute to Food Security	Adly Abdalla
Fiji	FIJ5003	Implementing Pesticide-Free Suppression and Management of Fruit Flies for Sustainable Fruit Production	Daguang Lu

Grenada	GRN0001	Building National Capacity through the Applications of Nuclear Technology	Rui Cardoso Pereira
Guatemala	GUA5021	Strengthening National Capabilities for the Control of Agricultural Pests Using Nuclear Technologies	Walther Enkerlin
Israel	ISR5021	Assisting in the Development of a Strategy to Counteract *Bactrocera zonata*	Walther Enkerlin
Jamaica	JAM5014	Establishing a Self-Contained Gamma Irradiation Facility for the Introduction of Sterile Insect Technique and Experimental Mutagenesis and Diagnostic Technologies	Rui Cardoso Pereira
Libya	LIB5014	Supporting Control of Fruit Flies by Establishing a Low Fruit Fly Prevalence Zone	Daguang Lu
Mauritius	MAR5026	Sustaining the Suppression of *Aedes albopictus* in a Rural Area with Possible Extension to An Urban Dengue-Prone Locality through Integrated Vector Management Strategy	Maylen Gómez
Mexico	MEX5032	Scaling Up the Sterile Insect Technique to Control Dengue Vectors	Kostas Bourtzis
Morocco	MOR5038	Strengthening the Use of the Sterile Insect Technique	Walther Enkerlin Carlos Cáceres
Palau	PLW5003	Facilitating Sustainability and Ensuring Continuity of Area-wide Pest Management — Phase III	Daguang Lu
Senegal	SEN5040	Strengthening National Capacities to Create a Tsetse-Free Zone Using the Sterile Insect Technique	Marc Vreysen
South Africa	SAF5015	Supporting the Control of Nagana in South Africa Using an Area-wide Integrated Pest Management Approach with a Sterile Insect Technique Component - Phase I	Marc Vreysen
South Africa	SAF5017	Assessing the Sterile Insect Technique for Malaria Mosquitoes — Phase III	Hanano Yamada
Seychelles	SEY5012	Establishing Area-wide Integrated Pest Management by Using the Sterile Insect Technique in Combination with Other Control Methods on the Suppression of the Melon Fly	Rui Cardoso Pereira
Sudan	SUD5038	Implementing the Sterile Insect Technique for Integrated Control of *Anopheles arabiensis*, Phase II	Adly Abdalla
Turkey	TUR5026	Conducting a Pilot Program on Integrated Management of *Aedes aegypti* Including Sterile Insect Technique	Maylen Gómez
United Republic of Tanzania	URT5034	Implementing Pre-Operational Activities for the Elimination of *Glossina swynnertoni* through Area-wide Integrated Pest Management with a Sterile Insect Technique Component	Chantel de Beer
United Republic of Tanzania	URT5035	Implementing the Sterile Insect Technique as Part of Area-wide Integrated Pest Management for Controlling Invasive Fruit Fly Populations	Daguang Lu

Viet Nam	VIE5021	Integration of the Sterile Insect Technique with Other Suppression Methods for Control of *Bactrocera* fruit flies in Dragon Fruit Production	Rui Cardoso Pereira
		Ongoing Regional Projects	
Regional Africa	RAF5074	Enhancing Capacity for Detection, Surveillance and Suppression of Exotic and Established Fruit Fly Species through Integration of Sterile Insect Technique with Other Suppression Methods	Daguang Lu
Regional Africa	RAF5080	Supporting Area-wide Tsetse and Trypanosomosis Management to Improve Livestock Productivity - Phase IV	Maylen Gómez
Regional Asia & the Pacific	RAS5082	Managing and Controlling *Aedes* Vector Populations Using the Sterile Insect Technique	Marc Vreysen Hamidou Maiga
Regional Asia & the Pacific	RAS5086	Assessing the Efficiency of the Sterile Insect Technique for the Control of the Cocoa Pod Borer	Marc Vreysen
Regional Asia & the Pacific	RAS5090	Advancing and Expanding Area-wide Integrated Management of Invasive Pests, Using Innovative Methodologies Including Atomic Energy Tools	Walther Enkerlin
Regional Europe	RER5026	Enhancing the Capacity to Integrate Sterile Insect Technique in the Effective Management of Invasive *Aedes* Mosquitoes	Wadaka Mamai
Regional Latin America	RLA5075	Strengthening the Regional Capacities in the Prevention and Progressive Control of Screwworm	Walther Enkerlin
Regional Latin America	RLA5082	Strengthening Food Security through Efficient Pest Management Schemes Implementing the Sterile Insect Technique as a Control Method	Walther Enkerlin
Regional Latin America	RLA5083	Enhancing Capacity for the Use of the Sterile Insect Technique as a Component of Mosquito Control Programs	Maylen Gómez
Regional Latin America	RLA5084	Developing Human Resources and Building Capacity of Member States in the Application of Nuclear Technology to Agriculture	Rui Cardoso Pereira
		New National Projects in 2022	
Bangladesh	BGD5035	Validating the Sterile Insect Technique as a Key Component of an Area-Wide Integrated Pest Management Programme Against *Aedes aegypti* in Dhaka	Maylen Gómez
Burkina Faso	BKF5023	Implementing the Sterile Insect Technique to Reduce Wild Populations of *Aedes aegypti* and Tsetse	Adly Abdalla Maylen Gómez
Bolivia	BOL5023	Fruit Fly Control in Bolivia Using Integrated Pest Management Including the Sterile Insect Technique	Walther Enkerlin
Chad	CHD5011	Implementing the Sterile Insect Technique to Control *Glossina fuscipes fuscipes* — Phase II	Adly Abdalla Chantel de Beer

Cameroon	CMR5026	Supporting the National Fruit Fly Management Programme	Daguang Lu
China	CPR5027	Demonstrating Feasibility of the Sterile Insect Technique in the Control of the Codling Moth, *Cydia pomonella*	Walther Enkerlin
Cyprus	CYP5020	Developing a National Rapid Response Strategy for the Prevention of the Establishment of the Asian Tiger Mosquito	Jeremy Bouyer
El Salvador	ELS5015	Integrated Management of Fruit Flies using the Sterile Insect Technique to Establish Areas of Low Prevalence of Fruit Flies	Walther Enkerlin Daguang Lu
Ethiopia	ETH5023	Enhancing Livestock and Crop Production through Consolidated and Sustainable Control of Tsetse and Trypanosomosis to Contribute to Food Security	Chantel de Beer
Israel	ISR5022	Establishing the Sterile Insect Technique Methodology for the Management of the False Codling Moth, *Thaumatotibia leucotreta*, And Enhancing Integrated Pest Management Against the Peach Fruit Fly, *Bactrocera zonata*	Walther Enkerlin
Mauritius	MAR5028	Enhancing National Capabilities on the Suppression of Aedes Albopictus in an Urban Locality Using the Sterile Insect Technique as Part of an Integrated Vector Management Strategy	Maylen Gómez
Myanmar	MYA5029	Improving Fruit Yield and Quality by Using Sterile Insect Techniques as Part of Area-Wide Integrated Pest Management of Fruit Flies in the Mandalay Region	Daguang Lu
Portugal	POR5006	Integrating the Sterile Insect Technique in the Control of the Invasive Vector Mosquito *Aedes albopictus*	Maylen Gómez
Sudan	SUD5042	Implementing the Sterile Insect Technique for Integrated Control of *Anopheles arabiensis* — Phase III	Adly Abdalla
Turkey	TUR5027	Implementation of SIT for Suppression and Eradication of Medfly in Turkey	Daguang Lu
		New Regional Projects in 2022	
Regional Africa	RAF5087	Enhancing Regional Capacity for the Implementation of the Sterile Insect Technique as a Component for Area-Wide Tsetse and Trypanosomosis Management (AFRA)	Maylen Gómez
Regional Asia & the Pacific	RAS5095	Enhancing the Capacity and the Utilization of the Sterile Insect Technique for *Aedes* Mosquito Control	Marc Vreysen
Regional Asia & the Pacific	RAS5097	Strengthening and Harmonizing Surveillance and Suppression of Fruit Flies	Daguang Lu Rui Cardoso Pereira
Regional Latin America	RLA5087	Validating the Sterile Insect Technique for the Control of the South American Fruit Fly (ARCAL)	Walther Enkerlin
Regional Latin America	RLA5088	Advancing Surveillance and Progressive Control of the New World Screwworm Using the Sterile Insect Technique	Walther Enkerlin

Highlights of Technical Cooperation Projects

Enhancing Capacity for Detection, Surveillance and Suppression of Exotic and Established Fruit Fly Species through Integration of Sterile Insect Technique with other Suppression Methods (RAF5074)

Integrated Control of *Bactrocera dorsalis* with SIT in a Mango Orchard in Mauritius

In Mauritius, fruit flies are key pests of fruits and cucurbits. The recently introduced the oriental fruit fly, *Bactrocera dorsalis*, is by far the most dominate fruit fly species in mango orchards followed by *B. zonata*, *Ceratitis quilicii* and *C. capitata*. It was first detected in Mauritius in 1996 and then declared eradicated in 1999. A second interception was made in 2013 and it was eradicated again in 2014. The insect reinvaded a third time in 2015 and since then, it has spread to the whole island.

Fruit fly trap deployed in a mango orchard (photo: Preeaduth Sookar).

A pilot study on the integrated control of *B. dorsalis* combining the SIT with other control methods was carried out in an isolated mango orchard of about two hectares which is found in the west of the island. Another mango orchard, about 10 km away which received no treatment was taken as control. Since May 2020, ten fruit fly traps baited with methyl eugenol and insecticide were placed inside each orchard. The traps were serviced on a fortnightly basis. Weekly application of modified waste brewery yeast mixed with insecticide started in June 2020 in the treated orchard. Mass-trapping of male *B. dorsalis* was done with the placement of male annihilation technique (MAT) blocks impregnated with methyl eugenol and malathion ultra-low volume (ULV). In November 2020, the fly population dropped below 0.1 fly/trap/day, and the release of sterile flies was initiated and carried out on a weekly basis.

Ground releases at a density of 1 000 sterile male flies per hectare were carried out using paper bags till the end of the season in March 2021. Mango fruits were sampled from both orchards on a weekly basis and incubated in the laboratory to determine fruit fly infestation level. The percentage of mango fruits with fruit fly damage was reduced to less than five percent in the MAT-SIT treated orchard while infestation was above 40% in the untreated orchard.

Advancing and Expanding Area-Wide Integrated Management of Invasive Pests, Using Innovative Methodologies Including Atomic Energy Tools (RAS5090)

Regional Coordination Meeting, 19 May 2021 (virtual)

The aim of the meeting was to present progress made in the implementation of project activities during 2020 and to review the 2021 workplan. All project Member States (Israel, Jordan and the Palestinian Territories) participated. Despite the limitations imposed by the COVID-19 pandemic, a number of activities were implemented on-site by the Member States and through virtual means.

The trapping network against invasive fruit fly species was set-up in the region and has been kept active as well as the surveillance efforts against the desert locust threat, red palm weevil and other invasive species such as the fall armyworm. The project supplied equipment and materials to the three Member States to support the surveillance networks against invasive quarantine insect pests threatening the region.

The Middle East Database for Non-Indigenous Pests (MEDNIP), a regional phytosanitary platform, was very useful in the exchange of information and preparedness against the desert locust. Jordan managed to contain the spread of the pest, therefore protecting Israel and the Palestinian Territories. This is another clear example of the importance of regional cooperation against invasive transboundary insect pests.

The meeting also reviewed the status of the suspension since December 2019 of sterile Mediterranean fruit fly releases over the citrus production areas in the Jordan Valley due to the high cost of the sterile flies supplied by a facility in Israel and the limitations resulting from the COVID-19 pandemic.

A virtual workshop on the MEDNIP was also implemented from 26 to 28 July 2021 for training of the new project counterparts from Jordan and the Palestinian Territories.

Using the Sterile Insect Technique to Apply a Local Strain in the Control of *Aedes aegypti* (BRA 5061)

Nuclear Science to Control Mosquitoes. Director General Grossi's Visit to Brazil

Brazil is a key IAEA partner, and the exchange of knowledge between the Agency and Brazilian experts in the peaceful uses of nuclear science can benefit both and beyond, Director General Rafael Mariano Grossi said during his visit to the country, where, among others, he visited an IAEA-supported project to use a nuclear technique to combat mosquitoes that transmit Zika and dengue.

Sterile Aedes aegypti *male mosquitoes are being released weekly in a pilot project in the Brasilia Teimosa neighbourhood of Recife, Pernambuco (Photo: D. Calma/IAEA).*

The week-long visit, Mr Grossi's first to Latin America since he took office in 2019, kicked off in the city of Recife, where he participated in insect releases as part of an IAEA-supported programme to use the sterile insect technique (SIT) to control mosquitoes in the neighbourhood of Brasilia Teimosa. The SIT is a type of birth control for insects, where male insects are mass-reared and then sterilised using radiation. They are then released in large numbers to mate with wild females, resulting in no offspring and therefore contributing to a decline over time in the mosquito population. The method has been used for decades to control agricultural pests such as the Mediterranean fruit fly and New World screwworm fly and has recently been developed against mosquitoes.

The project implementing partner, Moscamed Brasil, provides one of the first SIT facilities in the world to mass-rear sterile *Aedes aegypti* mosquitoes for release, targeting two municipalities in the Brazilian states of Bahia and Pernambuco, which were particularly hard-hit by Zika in 2016. The IAEA has provided support to Moscamed Brasil since 2005 and facilitated the transfer of a gamma cell irradiator in recent years to scale up the production of sterile insects.

"What we see here is nuclear science for development, improving the lives of people," Mr Grossi said in Recife. "The result of the pilot trials in Recife to use SIT to fight Zika, dengue and other diseases will be important not only to Brazil, but worldwide."

Since October 2020, between 250 000 and 350 000 sterile males have been released weekly over a 60-hectare surface area. The releases – the first in an urban setting – have already resulted in a 19 percent reduction in the wild mosquito population in the area. Moscamed Brasil was designated an IAEA Collaborating Centre in 2018, and now provides experts and training for countries such as Mauritius, South Africa and Thailand.

Enhancing the Capacity to Integrate the Sterile Insect Technique in the Effective Management of Invasive *Aedes* Mosquitoes (RER5026)

Group Fellowship on Field Quality Assessment of SIT and other Control Methods against *Aedes* Mosquitoes in Europe. 13–23 September 2021, Valencia, Spain

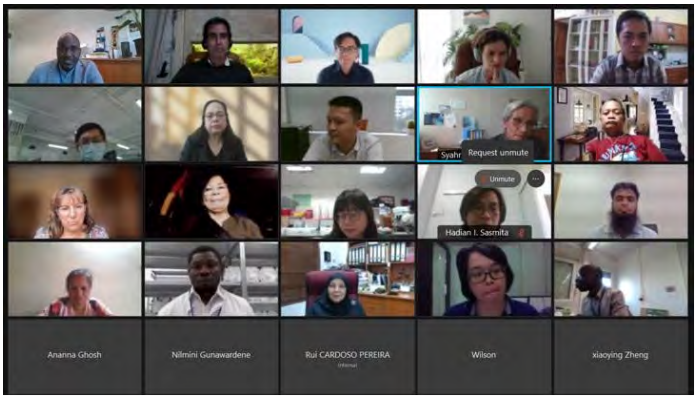
With increasing trade and travel, several *Aedes* species have been introduced into Europe and are now spreading rapidly, becoming a widespread significant public health risk which needs to be effectively addressed, as testified by recent cases of autochthonous chikungunya and dengue transmission. However, most pest control operators operate without harmonization of best control practices and coordination. As a result, the efficacy and the impact of vector control are often suboptimal and without any input from predictive models and novel control tools. Most often, novel control tools that require more engagement and investment are ignored. To protect the health of European citizens, higher efficacy of SIT and other control methods is the most pressing need. Therefore, the IAEA through TC Project RER5026 and the *Aedes* Invasive Mosquito (AIM) European Cooperation in Science and Technology (COST)/French MediLabSecure partners organized a joint group fellowship on 'Field quality Assessment of SIT and other Control Methods against *Aedes* mosquitoes in Europe'.

The fellowship was held in Valencia, Spain on 13–23 September 2021. This group fellowship provided participants with theoretical and practical knowledge on quality control requirements of integrated control measures including larvicide, adulticide, sanitation and sterile insect technique (SIT) treatments. Participants and beneficiaries were European countries participating in RER5026 (Albania, Bulgaria, Croatia, Cyprus, Greece, Portugal, Romania).

Managing and Controlling *Aedes* Vector Populations Using the Sterile Insect Technique (RAS5082)

FAO/IAEA Workshop on the Design and Evaluation of Mosquito Population Suppression Pilot Trials including Epidemiological Analysis, 6–10 September 2021 (virtual)

The overall objective of TC project RAS5082 is to provide capacity building to support the suppression of *Aedes aegypti* and *Aedes albopictus* mosquito vector populations using SIT-based approaches. To achieve this objective, the project plans to support, among others, pilot trials of sterile male mosquito releases conducted in selected field sites. This workshop was arranged to provide opportunities for participating countries to learn and exchange experience and expertise in setting up such pilot trials.



Participants of the Virtual Workshop on the 'Design and Evaluation of Mosquito Population Suppression Pilot Trials including Epidemiological Analysis', 6–10 September 2021.

The workshop was held virtually on 6–10 September 2021 with 16 participants from 8 countries (Bangladesh, China, Indonesia, Malaysia, Philippines, Singapore, Sri Lanka, Thailand) as well as five experts from WHO, Singapore and Cuba. With a main focus on epidemiological endpoints, the purpose of the workshop was to: (1) discuss a model design for mosquito population suppression pilot trials in the Asian and Pacific region, (2) evaluate the recent pilot trials in the region. Special consideration was given to the constraints, gaps and challenges in the implementation of field pilot projects, and (3) promote awareness of area-wide integrated pest management approaches and the Phased Conditional Approach implementation strategy. The workshop consisted of (1) expert presentations on model designs for mosquito population suppression pilot trials, (2) updates and review of pilot trials in the region, and (3) interactive discussion by workshop participants on individual case studies. The workshop benefited from the WHO knowledge and experience on epidemiological assessment of new technologies against mosquito-borne diseases. Recommendations for epidemiological trials were based on the joint WHO-IAEA Guidance Framework for Testing the Sterile Insect Technique as a Vector Control Tool against *Aedes*-Borne Diseases.

Enhancing Capacity for the Use of the Sterile Insect Technique as a Component of Mosquito Control Programs (RLA5083)

Regional Training Course on SIT Components: Methods for Mass-Rearing and Irradiation of *Aedes* Mosquitoes, 15–18 June 2021 (virtual)

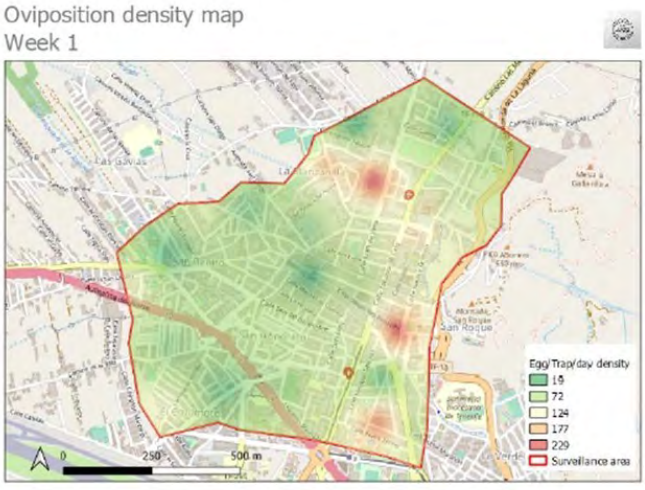
The training course focused on technical aspects of mass-rearing and irradiation of mosquitoes, as key components of the SIT package. The participants included 43 professionals and technical staff from 15 Member States of the Latin America and Caribbean region. Two experts, Mr Dongjing Zhang (Researcher from the Guangdong Provincial Engineering Technology Research Center for Diseases-vectors Control, Sun Yat-sen University, China) and Ms Rachel Morreale (Applied Science and Technologies Manager at the Lee County Mosquito Control District, USA) also participated in the training. The objective of the training course was to develop and enhance knowledge, and capability on the following topics: (1) strain colonization and evaluation of life history traits; (2) the process flow of sterile male production; (3) critical factors impacting the dose-response in mosquito irradiation and quality control of sterile males as part of the Phased Conditional Approach.

Improved prototype of mosquito mass-rearing cages as part of recent developments and advances with the development of the mosquito SIT package at the Insect Pest Control Laboratory.

In addition, staff of the Insect Pest Control Laboratory provided an update on the recent development and advances in terms of mosquito mass-rearing and irradiation. An exchange session was also held in which advanced countries on mosquito SIT such as Brazil, China, Cuba, and the USA shared the lessons learned and challenges faced during the implementation of their SIT pilot trials. These countries also shared their rearing and irradiation protocols with the participants. At the end of the training, the project's upcoming targets and priorities related to mass-rearing and irradiation topics targeting *Aedes* species were discussed and agreed at the regional level. With this, the regional networking and capacities were strengthened and the information about SIT package at the regional level harmonized.

Regional Training Course on SIT Components: Mosquito Monitoring, Data Collection and Data Management, 27–30 July 2021 (virtual)

The training was held virtually as part of the prioritized activities of TC Project RLA5083 for 2021. The agenda consisted of theoretical and practical sessions covering the following topics: Mosquito biology and taxonomy, pilot site selection and basic criteria, mosquito baseline data collection, trapping and sampling procedures, entomological indicators analysis, the use of Geographic Information System (GIS) and spatial data management in mosquito SIT pilot trials. During the practical session, participants were shown how to create a monitoring network for their SIT projects, generate population density maps, and create a GIS project to support the field data collection and data management.



Example of a population density map showing the spatial distribution of mosquito eggs in a pilot area.

The training was attended by 38 professionals including the counterparts and technical staff involved in field activities and data management from 15 Member States of Latin America and the Caribbean Region (i.e., Argentina, Bahamas, Bolivia, Brazil, Chile, Cuba, Ecuador, Guyana, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, and Uruguay). The experts Mr Carles Tur (TRAGSA Group, Spain) and Mr Danilo Carvalho (FAO/IAEA) guided the technical and practical sessions. The knowledge, skills, and key procedures shared during the training course were very useful to help Member States with the preparation of mosquito SIT field projects and will also contribute to harmonize field data collection and analysis. As a result, field information can then be compared among Member States. At the end of the course, it was unanimously decided that the development of a guideline on mosquito baseline data collection will be top priority to enable harmonizing field procedures in SIT pilot trials in the Latin America and Caribbean region.

Regional Workshop on Communication Strategies for the Use of the Sterile Insect Technique as Component of Mosquito Control, 3–5 November 2021 (Spanish Group), 9–11 November 2021 (English Group) (virtual)

The workshop was conducted separately for Spanish-speaking countries (3–5 November) and English-speaking countries (9–11 November). The objective of this workshop was to provide technical assistance to participating Member States on developing communication strategies and the implementation plan for an effective engagement and mobilization of the stakeholders as well as the local communities that using those strategies focused on SIT interventions for mosquito control. The Member States provided their status update, in addition to their progress and challenges faced with effectively engaging with key stakeholders, organization partners, the community, and social groups during the process of assessing the SIT for mosquito control at the local level. Practical sessions were also organized to guide the Member States on the development of a stakeholders map and communication plans, as well as the different communication methods.

During the event, technical discussions about appropriate methods and mechanisms took place, considering the legal and ethical aspects, to involve and properly inform the stakeholders and the community about the project´s activities, its progress, and results after the SIT intervention. Thirty-five participants from different Latin America and Caribbean MSs attended the workshop including project counterparts, health project managers, and professionals, who have direct involvement in communication activities targeting mosquito control and the implementation of SIT pilot projects. The experts Ms Margaret Capurro (University of Sao Paulo, Brazil) and Ms Ariane Dor (National Council of Science and Technology (Conacyt)- Ecosur, Mexico) guided the technical and practical sessions in both languages.

Coordinated Research Projects (CRPs)

Project Number	Ongoing CRPs	Project Officer
D4.30.03	Integration of the SIT with Biocontrol for Greenhouse Insect Pest Management (2017–2022)	Carlos Cáceres
D4.20.17	Improvement of Colony Management in Insect Mass-rearing for SIT Applications (2018–2023)	Adly Abd Alla
D4.10.27	Assessment of Simultaneous Application of SIT and MAT to Enhance *Bactrocera* Fruit Fly Management (2019–2024)	Rui Cardoso Pereira
D4.40.03	Generic Approach for the Development of Genetic Sexing Strains for SIT Applications (2019–2024)	Kostas Bourtzis
D4.40.04	Mosquito Radiation, Sterilization and Quality Control (2020–2025)	Jeremy Bouyer
D4.10.29	Improving Rearing, Handling, and Field Components for Fruit Fly SIT Application (2021–2026)	Walther Enkerlin
D4.10.28	Improve the Mass-Rearing of Lepidoptera Pests for SIT Programmes (2022–2027)	Daguang Lu

Second RCM on Assessment of Simultaneous Application of SIT and MAT to Enhance *Bactrocera* Fruit Fly Management. 28–30 June 2021 (virtual)

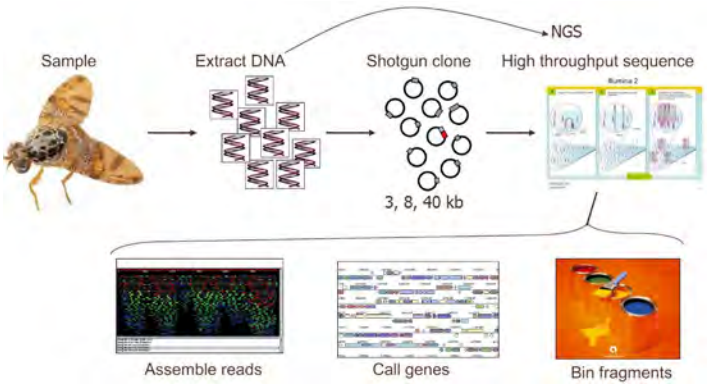
The RCM was held virtually with 38 research contract and agreement holders, as well as observers from Australia, Bangladesh, Brazil, China, Czech Republic, France, India, Israel, Malaysia, Mauritius, New Zealand, Pakistan, South Africa, Thailand, United States of America, Viet Nam and the International Centre of Insect Physiology and Ecology (ICIPE).

Carambola fruit fly infesting the host that give its common name.

The participants delivered 20 presentations on the progress with their research activities. The presentations covered all six research themes of the CRP, including, (1) pre-release treatment methodology for reduced lure response; (2) effects of pre-release treatments on fly performance; (3) novel attractants - microbiota, cuticular lipids, and plant extracts; (4) selection for non-responders; (5) mechanisms of lure response and (6) semi-field and field assessments of SIT +/- MAT. The Logical Framework and individual five-year workplan were also reviewed during the meeting. Nine peer reviewed scientific papers were published during the past two years.

Second RCM on Improvement of Colony Management in Insect Mass-rearing for SIT Applications. 30 August–3 September 2021 (virtual)

The RCM was held virtually with 21 participants and 29 observers from 18 countries including Argentina, Australia, Brazil, Burkina Faso, Cameroon, Canada, France, Germany, Greece, Guatemala, Israel, Italy, Kenya, Mexico, Netherlands, Spain, United Republic of Tanzania and United States of America.



Outlines of the meta-transcriptomic approach used to identify insect symbiont and pathogen in the frame of the CRP presented by Dr George Tsiamis in the 2nd RCM virtual meeting.

The first two days of the meeting were devoted to presentations whereas during the remainder of the meeting the participants discussed the major achievements and the recommendations in three working groups online on tsetse, fruit flies and insect pathogens. During the discussion it was concluded that the CRP made important progress in developing new GSS of the Mediterranean fruit fly to facilitate the refreshment of the colony with wild materials as well as developing and evaluating bi-environmental cage. In addition, the discovery of new viruses in fruit flies and tsetse was highlighted. Moreover, the complete genome of several gut bacterium has been initiated.

Second RCM on Generic Approach for the Development of Genetic Sexing Strains for SIT Applications. 18–22 October 2021, Vienna, Austria (hybrid)

The RCM was held in Vienna and attended by 24 scientists from Argentina, Australia, Cameroon, Canada, China, Czech Republic, France, Germany, Greece, Guatemala, Israel, Italy, Mexico, Pakistan, South Africa, Switzerland, Thailand, United Kingdom and United States of America, with 13 of them participated in person. In addition, 24 observers from Argentina, Australia, France, Germany, Greece, Israel, Italy, Netherlands, Thailand, United Kingdom and United States of America attended this meeting, with 6 of them attended in person.

Twenty-six scientific communications on modern biotechnology methods with the main emphasis being on the identification and characterization of genes that can be used as selectable markers for the construction of genetic sexing strains (GSS) were presented at the meeting. In addition, there were presentations on how modern biotechnology methods can be applied for the insertion of specific sequences in or near to male determining regions as well as on the characterization of maleness factors and sex determination pathways of insect pests and disease vectors targeted by sterile insect technique applications.

Participants of the Second RCM on Generic approach for the development of genetic sexing strains for SIT applications, Vienna, Austria.

During the discussion it was concluded that the CRP has been very productive, despite the pandemic posed by COVID-19, since several genes encoding for visible traits were identified and some of them (e.g. the white pupae gene) were shown to be suitable as generic markers for the construction of GSS for at least some of the SIT targeted tephritid species.

First RCM on Improving Rearing, Handling, and Field Components for Fruit Fly SIT Application. 1–5 November 2021 (virtual)

Fruit flies are one of the most destructive pests affecting production and international trade of fruits and vegetables worldwide. As such, fruit fly pests are a significant constraint in reaching the sustainable development goals of the UN by affecting food security and safety as well as poverty reduction and the environment.

In the past decades the sterile insect technique (SIT) has been successfully incorporated in integrated fruit fly management against some of the most important fruit fly pests. The SIT has been used for pest exclusion, containment, suppression, and eradication. Examples of successful high impact SIT interventions against fruit fly pests include operational programmes in Argentina, Australia, Chile, Croatia, Guatemala, Israel, Mauritius, Mexico, Peru, Spain, Thailand and the USA.

Nevertheless, technological gaps, lack of harmonization of technologies and tools, and lagging adaptation of technological innovations have been observed in operational programmes in Member States. This situation applies to various components of SIT used against fruit fly pests, including colony management, mass-rearing of insects, sterilization and post-irradiation handling and release. It can also be observed in field components including surveillance systems and population suppression methods. Applied research is required to adopt these novel technologies in more operational programmes and to improve cost effectiveness.

Mediterranean fruit fly breeding colonies at El Pino Guatemala (photo: Programa Moscamed Guatemala).

Optimization and harmonization of SIT will further provide comparative advantages to this nuclear based technology.

To address this situation, a virtual consultancy meeting was held from 7–11 June 2021. The consultants together with staff of the Insect Pest Control Section of the Joint FAO/IAEA Centre, formulated a proposal for a new five-year CRP entitled 'Improving Rearing, Handling, and Field Components for Fruit Fly SIT Application'. The proposal was approved by the IAEA's Research Contract Administration and the first Research Coordination Meeting of the CRP was held virtually from 1–5 November 2021. It was attended virtually by 19 scientists of research institutes from Argentina, Australia, Brazil, Burkina Faso, Guatemala, Israel, Mauritius, Mexico, South Africa, Spain, United States of America, and Viet Nam. In addition, the virtual meeting allowed for the participation of additional 61 observers, which was beneficial for the institution's research groups. The thematic research areas were grouped into three major categories each with specific research topics: 1) Production Process (genetic sexing strains (GSS) and gel diets), 2) Post-production Process (supplements and sterile fly release) and 3) Field Operations (trapping and bait stations).

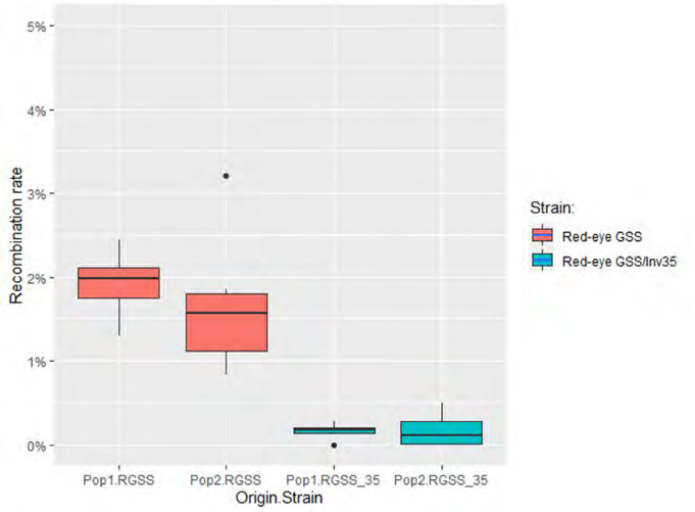
Developments at the Insect Pest Control Laboratory (IPCL)

Genetics and Molecular Biology

Aedes aegypti Red-Eye Genetic Sexing Strain Introgressed Into Different Genomic Backgrounds

Aedes aegypti is a major vector of arthropod-borne viruses (arboviruses) with detrimental effects for the society and economy of the affected countries. Population suppression strategies, such as the sterile insect technique (SIT) as a component of area-wide integrated pest management (AW-IPM) programmes, have been suggested as a sustainable alternative to the control methods applied to date, which are largely based on insecticides. Mosquito SIT requires an efficient and robust method for sex separation since female mosquitoes are the ones that bite, blood feed, and potentially transmit the pathogens.

A genetic sexing strain (GSS) that is based on a red eye morphological marker was recently developed which allows the separation of black-eye males from red-eye females. The *Ae. aegypti* Red-eye GSS has been developed using classical genetics and its quality control profile demonstrated its remarkable performance and genetic stability under laboratory conditions (Koskinioti et al., 2021. https://doi.org/10.1098/rstb.2019.0808). An irradiation-based inversion (Inv35) was introduced in the GSS resulting in improved genetic stability and drastically reduced probability of female contaminants in the male release batches (Augustinos et al., 2020. https://doi.org/10.1186/s12863-020-00949-w).



Recombination frequencies of Aedes aegypti *red-eye genetic sexing strain (RGSS) introgressed into two different genomic backgrounds (Pop1 and Pop2) with and without Inv35.*

It has been suggested that population suppression programmes, which are based on the release of sterile males, should ideally use strains of local origin. This will not only maximize the successful matings between released males and wild females, but it will also address potential biosafety and biosecurity concerns by the public stakeholders. So, any future operational SIT programme that will employ the Red-eye GSS (either with or without the inversion) should ideally be carrying the local genomic background of the targeted population.

To address these important points, we received six different *Ae. aegypti* wild populations and, through a series of genetic crosses, we introgressed the red eye mutation and the inversion Inv35 lines into the new genomic backgrounds. The introgression scheme ensured that the strains produced were carrying about 99% of the local genomic background. We investigated whether the different genomic backgrounds affected the genetic sexing features and the recombination frequencies in the newly developed GSS with and without the inversion. Our results indicate that the genetic sexing properties of the strains were not affected, and the recombination events were drastically suppressed in all Inv35 GSS strains, thus ruling out the possibility of increased recombination attributed to the local genomic background. Maintaining the local background also minimizes any potential mating incompatibility effects and enhances the odds for increased male mating competitiveness. In addition, release of mosquitoes that carry the same genomic background to their wild counterparts addresses any potential biosafety concern and significantly enhances the public acceptance towards AW-IPM programmes with an SIT component.

Aedes aegypti red eye Gene

The red eye colour of *Aedes aegypti* is a naturally occurring mutation (the wild type colour is black). Genetic analysis has shown that the gene responsible for this phenotypic trait is recessive, sex-linked (mapped to chromosome I) and it presents full penetrance and expressivity. It has also been shown that the *red eye (re)* gene is closely linked to the M locus, and the genetic distance has been estimated to 2-3 cM. Despite this prior knowledge, the causal gene for the red eye phenotype in *Ae. aegypti* was not known until recently.

Aedes aegypti presents a low per megabase recombination rate and its chromosomes are dominated by large regions of suppressed recombination. In the frame of the coordinated research project (CRP) on 'Generic approach for the development of genetic sexing strains for SIT applications' and in collaboration with Prof. Jake Tu's research group (Virginia Tech, member of the CRP), a marker-assisted-mapping (MAM) strategy was developed that allows for screening and genotyping of the rare but informative recombinants, thus enhancing the resolution and signal-to-noise ratio and

overcoming the low recombination rate barriers (Chen et al., 2021. https://doi.org/10.1101/2021.04.29.442065).

Using MAM, the *re* locus was mapped to the region between 271 Mbp and 278 Mbp of chromosome I and the possible red eye gene candidates included in this area were evaluated. Using introgressed *Ae. aegypti* red-eye GSS in different genomic backgrounds, genome sequencing, bioinformatics, and functional genetics approaches, it was determined that cardinal is the causal gene of the red eye phenotype, which also confirms reports on diamond back moth *Plutella xylostella*. The cardinal gene encodes a peroxidase which catalyzes the formation of the eye pigment xanthommatin from 3-hydroxykynurenine in the ommochrome synthesis pathway and its identification in *Ae. aegypti* will assist in the development of GSS for several mosquito species, including *Aedes albopictus* and *Anopheles* species.

Aedes albopictus Associated Microbiota and Radiation

Aedes albopictus represents a vector species of highly pathogenic arboviruses such as dengue, Zika and chikungunya. The AW-IPM approaches with an SIT component have been proposed for the population suppression of this major mosquito vector species. A key factor for the successful implementation of SIT is the availability of high-quality sterile males with the necessary longevity, flight ability and mating competitiveness which would allow them to compete with wild males for mating with wild females resulting in the suppression of the target population.

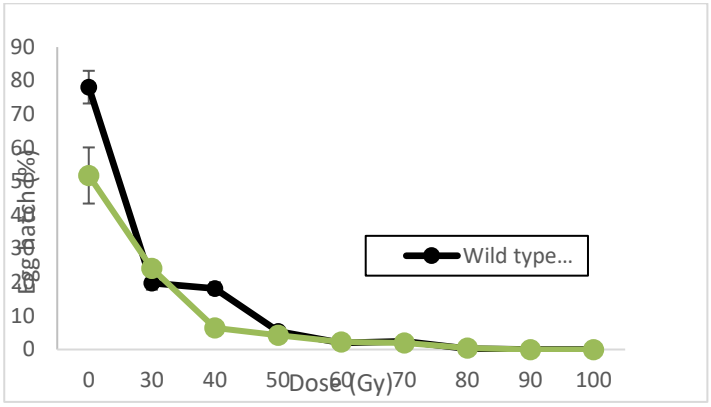
During the last two decades, a large number of studies have indicated that the gut-associated microbiota, and particularly the gut bacteriome, has an important role in the overall biology and ecology of insect host species. In addition, it has been shown with fruit flies that (a) radiation may affect the gut-associated bacterial communities both qualitatively and quantitatively and (b) the use of gut-associated bacterial species as probiotics may restore ecological fitness and biological quality of insects.

Given our prior knowledge on fruit flies, we assessed the effect of radiation on the gut-associated bacterial community of *Ae. albopictus* pupae and 1- and 4-day-old males and females using 16S rRNA gene-based next generation sequencing (NGS) and quantitative PCR (qPCR) approaches (Zhang et al., 2021. https://doi.org/10.3389/fmicb.2021.671699). The analysis indicated that radiation, age, and diet affect the structure of the bacterial community as well as the density levels of bacterial species with age being the factor with the most impact on bacterial diversity and structure of the gut-associated community in both pupae and adults. It also showed that *Aeromonas* is present in higher density in males samples compared to pupal and female samples and that irradiation results to increased levels of both *Aeromonas* and *Elizabethkingia* suggesting that gut-associated symbionts should be further characterized and potentially harnessed in support of mosquito mass-rearing and SIT applications.

Plant Pests

Sterilization Doses for Genetic Sexing and Bisexual Strains of *Anstrepha fraterculus* (Morphotype 1)

The South American fruit fly, *Anastrepha fraterculus*, is a pest that has a major impact on the fruit industry in South America. The SIT can be an additional component to manage this pest on an area-wide basis. Significant advances have been made with the development of an artificial rearing system that allows a rapid build-up of the colony and a production of larger number sterile flies that could be used to satisfy the demand of pilot-programmes against this pest. As reported in a previous newsletter, a genetic sexing strain (GSS) of *A. fraterculus* has been developed at the IPCL that is based on pupal colour dimorphism, i.e., the adult males emerge from brown pupae, whereas the females emerge from black pupae. Using this pupal colour phenotype, the females can be easily separated from the males allowing male-only releases in the field. This *A. fraterculus* GSS was developed from a laboratory population of the *A. fraterculus* morphotype 1, i.e. the population that is distributed in southern and northern Argentina. Ms Paloma Della Giustina, a fellow from Brazil has been assisting with an assessment of the effect of radiation on the GSS in comparison with the wild type strain from Vacaria, in southern Brazil. The experiment was carried out under an oxygen-reduced atmosphere, which is a commonly used protocol to protect fruit flies' pupae during irradiation treatment to minimize the impact on sterile male fly quality.

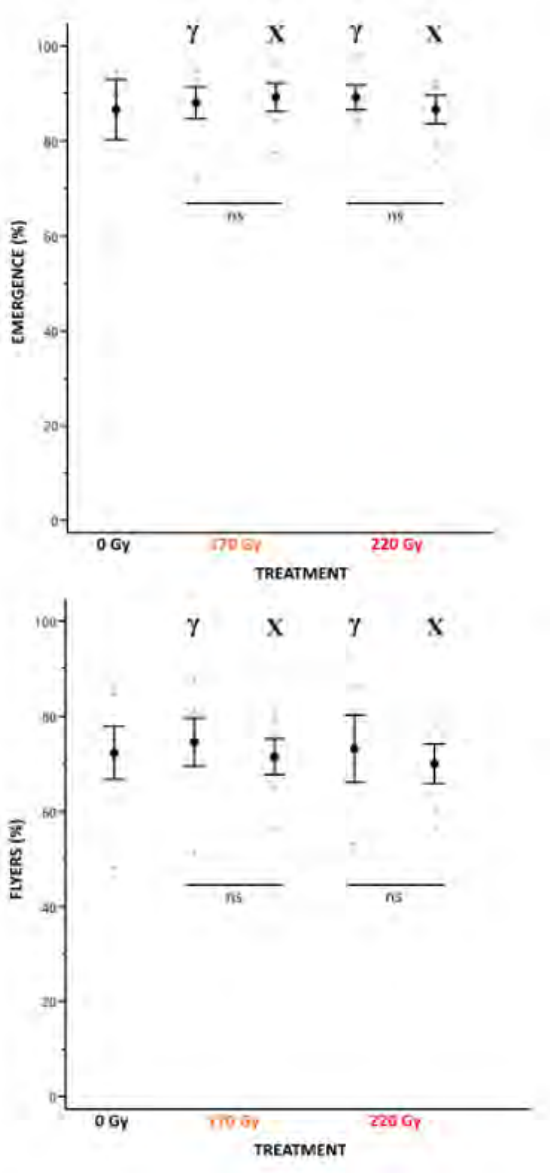


Dose-response curve for fertility (egg hatch) from crosses between fertile female Anastrepha fraterculus *and males from a genetic sexing strain (GSS) and a bisexual strain (Vacaria) irradiated under hypoxia (Giustina et al., 2021. https://doi.org/10.3390/insects12040308).*

This study tested a range of gamma radiation doses administered to pupae from a bisexual strain and the new GSS under hypoxia. Complete sterilization was achieved with a dose of 80 Gy. The quality of the sterile insects in terms of adult emergence was similar between strains, but slightly lower in comparison with an untreated control group. This information becomes valuable for the implementation of SIT against *A. fraterculus* in the region.

Developing the SIT Package for the Spotted Wing Drosophila (SWD)

Sterilization of *Drosophila suzukii* (SWD) males and females has been studied previously using isotopic irradiators. In this study, we compared the effects of gamma rays and X-rays on SWD induced sterility and sterile male quality. To this end, a self-contained ^{60}Co irradiator (Foss 812; Foss Therapy Services, CA, USA) and an X-ray blood irradiator (Raycell MK2; Best Theratronics, ON, Canada) were used. The radiation source did not affect the level of sterility after irradiation of the pupae with 170 and 220 Gy under low oxygen conditions. These were the doses initially proposed for SWD suppression and eradication strategies in a previous study (Sassù et al., 2019. https://doi.org/10.1371journal.pone.0226582). In addition, no effect of the radiation source was observed on fly emergence and sex ratio, flight ability, survival under stress, and mating competitiveness.



Drosophila suzukii *adult emergence and flight ability after irradiation of the pupae (two doses, 170 and 220 Gy, using the gamma and X radiation sources) or without irradiation (controls=0 Gy).*

In addition to the conclusion that X-ray irradiation could be a good alternative to gamma irradiation for SWD sterilization, this project has stimulated the development of quality control protocols for SWD, that will be described in a future publication. Further developments to evaluate the competitiveness of mass-reared sterile male SWD as compared with wild males under semi-natural conditions are still ongoing. For this purpose, a wild SWD population was established this summer from individuals collected on black elderberries in Lower Austria. In addition, a second upcoming publication will provide guidelines for mass-rearing and irradiation protocols adapted to SWD.

The FAO/IAEA/USDA Phytosanitary Treatment Project

The large-scale confirmatory tests evaluating the efficacy of a phytosanitary cold treatment for *Zeugodacus tau* (senso latu) were completed. A total of 36 512 third instars infesting navel oranges that were exposed to a cold treatment of < 1.7ºC for 22 days yielded four survivors that failed to emerge as fully formed adults. A manuscript summarizing these results has been submitted for publication.

Research evaluating dose rate effects on phytosanitary irradiation efficacy for *Ceratitis capitata* was completed. The phytosanitary irradiation treatment of 100 Gy proved to be effective against third instar *C. capitata* infesting mandarins regardless of dose rate. Significant dose distribution differences were observed while conducting dose rate experiments using a Foss 812 gamma irradiator. A paper summarizing these findings has been drafted and will discuss critical dosimetry aspects that are relevant for further studies evaluating dose rate effects on phytosanitary irradiation efficacy.

Mr Jonathan Aguilar (left), Ms Jennifer Andrade (center), and Ms Inajara Viana (right) dissecting blueberries infested with Drosophila suzukii *for phytosanitary irradiation research.*

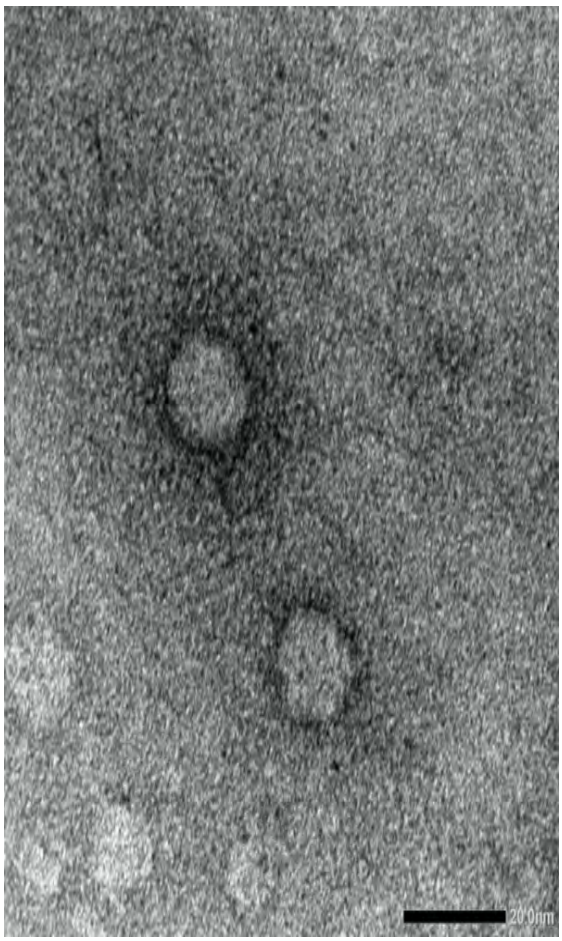
Confirmatory large-scale tests on phytosanitary irradiation for *Drosophila suzukii* have been conducted to validate the radiation dose of 80 Gy. Naturally infested blueberries containing pharate adults, the most tolerant stage of *D. suzukii*

associated with the fruit, were irradiated with 80 Gy of gamma rays and held in the laboratory to assess adult emergence, mating, and oviposition. A total of 26 030 pupae were treated. A few emerged irradiated adults were able to lay eggs, but these did not hatch, indicating no development to an F1 generation. Currently, there are neither adopted irradiation treatment schedules nor sufficient phytosanitary irradiation studies to support irradiation treatment schedules for *D. suzukii*. Results generated from this project have the potential to support an irradiation treatment recommendation to the Technical Panel on Phytosanitary Treatments (TPPT) of the International Plant Protection Convention (IPPC) that, if approved and adopted, could benefit the Member States of the FAO and IAEA.

Livestock Pests

Attempts for Isolation and Purification of Iflavirus and Negevirus Particles in *Glossina morsitans morsitans*

It is known that some tsetse fly species such as *Glossina morsitans morsitans* and *Glossina morsitans centralis* harbour two RNA viruses (Iflavirus and Negevirus) in addition to the four symbiont bacteria. The impact of these viruses on tsetse rearing is under-investigation.

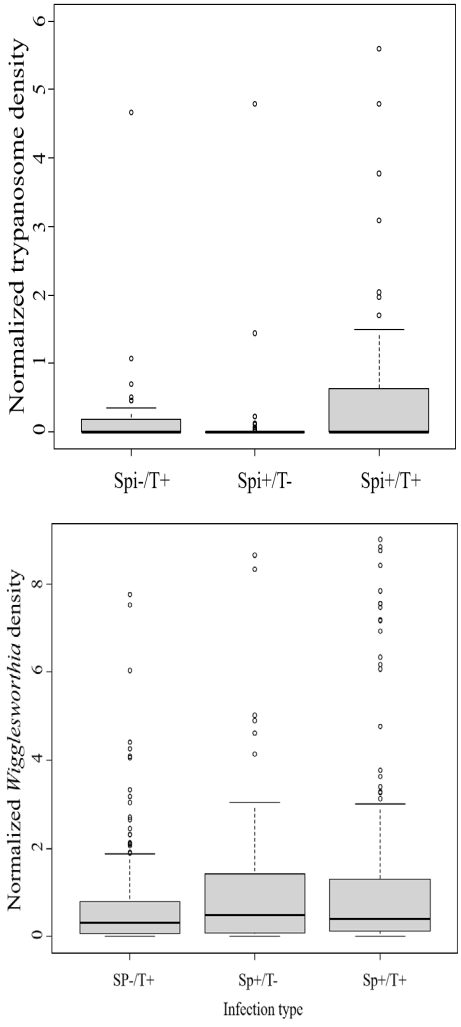


Purified viral particles isolated from Glossina morsitans morsitans *infected with Iflavirus and Negevirus observed under electron microscope (scale bar 20nm).*

To better identify these viruses, attempts were made to isolate and purify the virus particles from *G. morsitans morsitans* using a sucrose gradient ultra-centrifugation method. Purified viruses were observed under a transmission electron microscope. The observed viral particles were morphologically similar to Iflavirus detected in honeybees. PCR result confirmed the presents of Iflavirus and Negevirus and therefore further steps are needed to separate the two virus particles. This work was conducted by Ms Hannah Huditz, a PhD student from Austria in collaboration with Prof. Monique van Oers, Wageningen University.

Analysis of the Impact of *Spiroplasma* Infection on *Wiggleshworthia* and *Trypanosoma* Density

Tsetse flies are known to harbour three obligatory symbionts (*Wigglesworthia*, *Sodalis* and *Wolbachia*) and a fourth symbiont, *Spiroplasma*, was recently discovered, but does not have yet a well-defined role. However, we reported in the previous newsletter 97 that *Spiroplasma* infections have a negative impact on the productivity of *Glossina fuscipes fuscipes* laboratory colonies.



Interaction between Spiroplasma *infection on* Trypanosoma *(above) and* Wigglesworthia *(below).*

Moreover, we reported that *Spiroplasma* infection is prevalent in wild *Glossina fuscipes fuscipes* and *Glossina*

tachinoides populations. The interaction between *Spiroplasma* and the other symbionts (*Wigglesworthia*, *Sodalis* and *Wolbachia*), the salivary gland hypertrophy virus (SGHV) and *Trypanosoma* spp. remains however, to be elucidated. To explore these interactions, we screened wild populations of *G. tachinoides* collected in Burkina Faso and Ghana for the infection status of these organisms. The results indicated the absence of *Sodalis*, *Wolbachia* and SGHV, but some flies were infected with *Spiroplasma* or *Trypanosoma* or with both. We analysed the impact of *Spiroplasma* infection on *Trypanosoma* and *Wigglesworthia* density in wild *G. tachinoides* using relative qPCR. The results indicate no significant impact of *Spiroplasma* infections on densities of *Trypanosoma* and *Wigglesworthia*.

The Foss Model 812 ^{60}Co Self-contained Irradiator used in Tsetse SIT

The Foss Model 812 ^{60}Co is a self-contained gamma irradiator and a new addition to the irradiator resources of the IPCL. The system has a large capacity and can deliver variable dose rates. The model has three separate ^{60}Co rods that can be utilized individually or in combination. The samples can be positioned on three turntables of various diameters and dose rates can be attenuated up to eight times providing dose rates from milliSv to kiloSv per minute.

As the success of the SIT depends on the release of competitive sterile males into the natural habitat of the species targeted for control, it was necessary to assess the sterility and quality of the males that emerged from pupae irradiated with the Foss 812 irradiator.

The characterization and dose-mapping of the Foss 812 were done by Mr Yeudiel Gomez Simuta, a consultant from the Moscafrut Programme, Mexico (Gomez-Simuta et al, 2021, doi.org/10.1016/j.apradiso.2021.109859). Following this work, tsetse pupae were irradiated in air and at room temperature inside a pupal shipment box with a target minimum dose of 118 Gy. The box was placed in the vertical position. The pupae were exposed to all three ^{60}Co sources in the turntable three position, which led to a dose rate of 78.63 Gy/min. To monitor the radiation dose, HD-V2 Gafchromic films (mean uncertainty 4.36% at 95% CI) were placed in small white envelopes at three different levels of the box, i.e. at the bottom, middle and top of the pupal shipment box (see figure). An optical density meter (DoseReader 4, RadGen, Budapest, Hungary) was used to read the HD-V2 films, 24 h after exposure. Pupae samples that were placed with the HD-V2 films at the bottom, middle and top of the pupal shipment box were collected for adult emergence and sterility assessment.

From the HD-V2 film readings, the lowest dose of 103 Gy was observed at the bottom of the shipment box and the highest dose of 142 Gy at the top. On average, the pupae in the box received a dose of 120±6.0 Gy, 131±8.3 Gy, and 130±6.9 Gy at the bottom, in the middle and at the top, respectively, with a minimum target dose of 118 Gy.

Ms Arooj Nawaz preparing the male Glossina palpalis gambiensis *pupae to be sterilised with the Foss 812 gamma irradiator.*

Average emergence rates of 75±7.9% to 77±6.1% were observed for the pupae sampled from the bottom, middle and top of the pupal shipment box and were not significantly different. The males that emerged from the selected pupae were then mated at a 1:1 ratio with virgin females. The female production was followed for 60 days and the induced sterility determined. The lowest induced sterility (92.8%) was recorded in females that had been mated with males that originated from the bottom of the box. On average the induced sterility of females was the lowest when mated with males selected from the bottom of the box (96.7±1.9%) followed by males from the middle (97.7±1.4%) and the highest for males selected from the top of the box (98.9±1.2). Because of the unavoidable dose variability within the canister, highlighted again with the data above, many of the pupae received a too high radiation dose and this will decrease male quality and competitiveness.

The Foss 812 is currently being used for the sterilisation of *G. palpalis gambiensis* pupae that are shipped to the tsetse eradication programme in Senegal twice a week. The target minimum dose was adjusted to 108 Gy, to reduce the over exposure and an 10% increase in effective sterile flies were reported from the programme in Senegal.

Protocol for the Sex Sorting of Tsetse Pupae with the Near Infrared Pupal Sex Sorter

With the newly developed Near InfraRed Pupae Sex Sorter (NIRPSS), sex separation of tsetse pupae is now possible and is now routinely being used for the *Glossina palpalis gambiensis* eradication programme in Senegal. The pupae can now be sorted five days before emergence of the adults and the male pupae can be shipped long distance without using low temperature conditions to prevent emergence. As a result, a 20% increase in male quality has been recorded in the Senegal programme. The sorting protocol is available for *G. p.*

gambiensis pupae that are incubated at a constant temperature of 25°C and relative humidity of 80%. They can be sorted with an accuracy of 90% when the pupae are 24 days old, or about 6 days before emergence.

Ms Olga Soukia collecting the 'fliers' during the tsetse flight propensity quality control test, to assess the effect of the Near InfraRed Pupae Sex Sorter on the quality of the male tsetse flies.

The sorting protocol was also evaluated with the tsetse species *Glossina pallidipes*, a target vector in Ethiopia and *Glossina fuscipes fuscipes* a target vector in Chad. The pupae that were sorted were all deposited within a 10-hour period and incubated at a constant temperature of 25°C and relative humidity of 80%. The pupae were sorted daily with the NIRPSS when they were between 22-26 days old. A melanised to non-melanised ratio of 7:3 was needed to achieve 90% sexing accuracy, and this was obtained for *G. pallidipes* and *G. f. fuscipes* pupae sorted when they were 24 and 26 days old, respectively. Subsequently, the effect of NIRPSS on the quality of the males was also evaluated and no significant wing damage could be found and there was no significant negative affect on the male's ability to fly in both species.

The NIRPSS sorting protocol for three tsetse species is now available and will soon be expanded to include also *Glossina brevipalpis* a target vector in southern Africa.

Human Disease Vectors

Efficiency Assessment of the Wolbaki™ and the FAO/IAEA Mass-rearing Rack

The operational success of the SIT as a component of area-wide integrated pest management (AW-IPM) depends on being able to continuously produce and release good quality sterile males in large enough numbers to achieve appropriate sterile-to-wild male ratios. Since 2004, following the request from FAO and IAEA Member States, IPCL has been developing a package of equipment and protocols for the application of the SIT against disease transmitting mosquitoes. Significant progress has been made in the development of such equipment and protocols and several SIT pilot trials are now ongoing in various countries around the world. However, for the economic viability and sustainability of these SIT programmes, efforts are needed to improve the existing technologies to reduce the cost of sterile male production and increase their efficiency.

FAO-IAEA Aluminium rack **Wolbaki tray-rack system**

The two larval rearing rack systems that were assessed at the IPCL.

The Chinese Company Wolbaki Biotech has developed a new larval mass-rearing rack prototype (Model WBK-P0003-V2) based on the FAO/IAEA rack model (see figure) to mass-rear *Aedes albopictus*. This Wolbaki model consists of a mechanized stainless-steel rack able to hold up to 100 larval rearing trays (smaller than the FAO/IAEA trays). Trays are stacked in two blocks of 50 each in the whole rack that covers an area of 1.1 m^2 in comparison to 0.71 m^2 for the FAO/IAEA mass-rearing rack. Both racks are now being tested at IPCL to assess its efficiency to mass-rear *Aedes aegypti*.

The experiment was designed to (1) estimate and compare male and female pupae production per rearing tray, rack and surface unit, (2) estimate and compare the female contamination rate, (3) body size and (4) male flight ability.

Preliminary results show that the production of adult males and females as well as female and male body size were similar between the two rack systems. Conversely, percentage female contamination was lower and male flight ability was better for the FAO/IAEA unit. Moreover, in terms of production per surface unit and cost, the FAO/IAEA appeared more cost-effective than the Wolbaki rack. Considering the differences between rearing protocols, mosquito strains and our present results, the Wolbaki rack can be considered as an efficient system for the mass-rearing of *Ae. albopictus* without impacting the production and male quality.

Impact of Chilling and Anoxia on Irradiation of Adult Mosquitoes

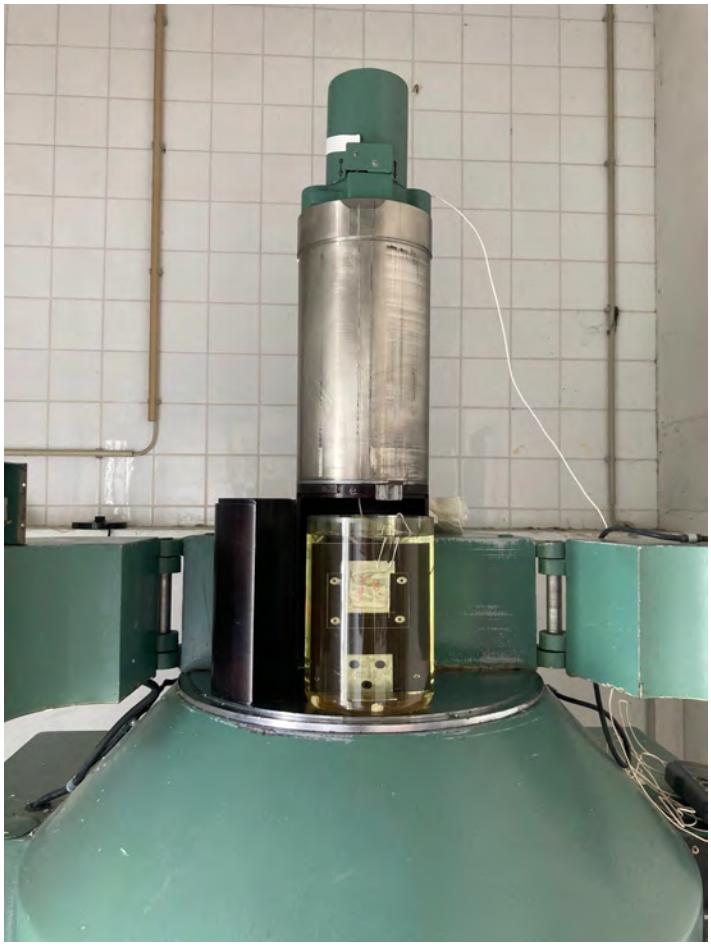
Following a series of experiments to identify physical and biological factors that affect dose-response in mosquito pupae, a study was initiated to assess the impact of external factors on adult mosquito dose response. Preliminary results with *Aedes albopictus* show that immobilizing methods such as chilling and anaesthetizing agents affect direct radiation effects and can also alter downstream male quality parameters. Chilling induces damage in insects, but partial or full recovery is possible if chilling duration and temperature are carefully controlled.

Adult Ae. albopictus *males in anoxia (nitrogen) and in air, in preparation for irradiation with 45 Gy.*

Irradiation in nitrogen has high radioprotective effects in adults, but higher irradiation doses are needed to achieve the desired sterility level. Longevity of males can be improved by irradiating in anoxia, however, the exposure to nitrogen itself comes with negative impacts on flight ability. Recovery of flight ability did not occur within two days, however, longer recovery phases were not tested. Irradiation in anoxia to improve male mating competitiveness has been reported in other insects but has yet to be evaluated in mosquitoes.

Use of Gafchromic™ Films for Dosimetry

Dosimetry is an essential component of any irradiation study. For any chosen dosimetry system, such as the use of radiochromic film, accuracy and reliability need to be warranted. For irradiation studies at the IPCL, Gafchromic™ films have been a standard component of irradiation work. Previously, the characteristics of the film included a sensitivity to temperature during radiation exposures, and a temperature correction was applied when calculating the absorbed dose.



Exposure of radiochromic films to gamma rays in temperature-controlled water baths.

Closer investigation of the newer versions of the HD (Dose Range: 10-1000Gy) and MD (Dose Range: 1-100Gy) films have recently shown that the response to these films is no longer sensitive to temperature and have improved in consistency of the absorption spectrum at various doses. These improvements will simplify the use and processing of the films for dose measurement.

Reports

Inauguration of the New Mediterranean Fruit Fly Mass Rearing and Sterilization Facility in Mexico

The Moscamed Programme is a tripartite international commission between Guatemala, Mexico and the USA established in 1977 in response to the Mediterranean fruit fly invasion in Guatemala and the State of Chiapas, Mexico in 1976 and 1977, respectively. In 1982, the Moscamed Programme declared the Mediterranean fruit fly eradicated from infested areas in the State of Chiapas, Mexico, using the sterile insect technique (SIT). Nowadays, the countries are considered international leaders in this technology because of its successful large-scale application and experience gained since the late 1970s'.

New state-of-the-art Mediterranean fruit fly mass rearing and sterilization facility in Metapa, Chiapas, Mexico (Photo: SENASICA).

On 29 August 2021, a new Mediterranean fruit fly mass-rearing and sterilization facility with a capacity to produce one billion sterile male flies weekly, was inaugurated in Metapa de Dominguez, Chiapas, Mexico. The ceremony was attended by the President of Mexico, the Governor of the State of Chiapas and the Secretary of Agriculture. In his inauguration speech, the President indicated that the new facility was instrumental in keeping the country free of this invasive pest protecting and supporting sustained production of fruit and vegetable products. He went one saying that despite the pandemic the agricultural sector in Mexico continued its growth being vital for the country's economy. In his intervention the Secretary of Agriculture indicated that the Mediterranean fruit fly is a devastating pest capable of causing serious economic and social damage by destroying the production and commercialization of horticultural products for small, medium and large producers.

The new facility in Metapa de Dominguez is the second largest facility of its kind in the world (after 'El Pino' fruit fly facility in Guatemala) using the most advanced fruit fly production and sterilization processes. Following FAO and IAEA guidelines, the newly state-of-the-art facility incorporated recent developments in its design, such as glass ceiling and walls to allow more natural light for the adult flies in the mother colony area, creating an overall more natural environment. It was built in the vicinity of the first facility which was set-up by the Moscamed Programme in 1977 and is still operational.

The new facility will guarantee the continued use of this nuclear technology, strengthening the pest containment barrier which is located between the borders of Mexico and Guatemala and, thus, protecting the horticultural production in Mexico, Guatemala and the USA.

Collaboration on Fruit Fly SIT between Mexico and the IAEA Continues

Due to its leadership and expertise, Mexico's Programa Nacional Moscas de la Fruta (PNMF), Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria (SENASICA), Secretaría de Agricultura y Desarrollo Rural (SADER), was designated in 2010 as an International Atomic Energy Agency (IAEA) Collaborating Centre.

Through this cooperation hundreds of professionals from Latin America, the Caribbean and other regions in the world have been trained in SIT application and the technology which has advanced through research and development conducted at PNMF, in close collaboration with the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture.

Ms Najat Mokhtar, IAEA Deputy Director General, handing over the plaque for the redesignation of the Programa Nacional Moscas de la Fruta (PNMF) as an IAEA Collaborating Centre to Mr Luis Javier Campuzano Piña, Mexico's Ambassador to Austria and Permanent Representative to the United Nations in Vienna.

In September 2021, the Centre was redesignated for a further four years (2021–2025) of collaborative work. During the

ceremony that took place at the IAEA's headquarters in Vienna, Ms Najat Mokhtar, IAEA Deputy Director General and Head of the Department of Nuclear Sciences and Applications, presented a commemorative plaque to Mr Luis Javier Campuzano Piña, Mexico's Ambassador to Austria and Permanent Representative to the United Nations in Vienna. High-level authorities of the counterpart institute including Mr Javier Trujillo, the Mexico National Director of Plant and Animal Health and Francisco Ramirez, Plant Protection Director General, attended the ceremony virtually.

"Synergies between these two institutions will allow a global multiplication of the impact of SIT and related technologies" said Ms Mokhtar. Ambassador Mr Campuzano mentioned "the redesignation of PNMF as an IAEA Collaborating Centre for another term, will undoubtably be a great opportunity for strengthening cooperation between Mexico and the IAEA, as well as multilateral collaboration in SIT technology for the benefit of many other countries".

Mr Trujillo indicated that "the newly inaugurated state-of-the-art facility located within the premises of the Collaborating Centre will provide hands-on exposure to the trainees from IAEA and FAO Member States to the most advanced technologies in the production and sterilization of fruit flies".

New IAEA Collaborating Centre in Burkina Faso to Support the Application of the Sterile Insect Technique for Tsetse Flies

The IAEA has designated the Insectary of Bobo Dioulasso-Campagne d'Eradication de la Mouche Tsétsé et de la Trypanosomose (IBD-CETT), Bobo Dioulasso, Burkina Faso, as an IAEA Collaborating Centre in Africa to develop the sterile insect technique (SIT) for the management of tsetse fly populations, a vector that transmits diseases that are harmful to both humans and animals (sleeping sickness in humans and nagana in livestock).

Ms Najat Mokhtar, IAEA Deputy Director General, handing over a plaque for the designation of the Insectary of Bobo Dioulasso Campagne d'Eradication de la Mouche Tsétsé et de la Trypanosomose (IBD-CETT) as an IAEA Collaborating Centre to Dieudonné Kere, Burkina Faso's Ambassador to Austria and Permanent Representative to the United Nations in Vienna.

This agreement, signed on 13 September 2021, will enhance the cooperation of the two organizations to promote the use of the SIT as a sustainable and environment-friendly control method to manage tsetse fly populations and trypanosomosis, one of Africa's most devastating diseases.

The IBD-CETT was inaugurated in February 2017 and is the largest tsetse fly mass-rearing facility in West Africa with a capacity of producing 300 000 sterile males per week. The IBD has been instrumental in providing the sterile male tsetse flies for the SIT programme to create a tsetse free zone in the Niayes of Senegal.

This collaboration will enable the IBD-CETT to continue being the driving force in the West African region with respect to promoting SIT for tsetse and an important centre for the training of technical staff in all aspects of the SIT for tsetse. The IBD will also continue to host important meetings, training courses and provide expert services as well as producing sterile males for SIT programmes in Burkina Faso and neighbouring countries. The IBD-CETT was involved in optimizing and validating methods for tsetse fly sex separation, packaging and long-distance shipment for improving the efficiency of SIT projects for tsetse control. This research complements activities of the Insect Pest Control Subprogramme within the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture.

Isolation of Gene Markers Leads to More Effective, Efficient Insect Pest Control

Fruit flies can be a nuisance in one's kitchen. More importantly, across farmlands around the world, these highly destructive pests can wreak havoc among fruit and vegetable production. Nuclear science and technology have helped to suppress such pests in an environment-friendly manner with the sterile insect technique (SIT). The IAEA, in cooperation with the Food and Agriculture Organization of the United Nations (FAO), has helped countries implement SIT, in which irradiation is used to sterilize insect pests and thereby suppress or eradicate their populations over time.

It is typically female insects that damage fruits by laying eggs in them. The SIT, during which hundreds of millions of insects are reared and released, needs to focus on the male insect, which do not destroy produce or cause economic damage. Therefore, the SIT is most efficient when males can be separated from females before irradiation. "The efficiency and cost effectiveness of the SIT is enhanced by male-only releases, which are usually achieved through separation methods, such as genetic sexing strains (GSS)," said Mr Konstantinos Bourtzis, a molecular biologist at the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture and co-author of a paper published earlier this year in Nature Communications. GSS enables the separation of large numbers of insects according to sex earlier in the insects' development cycle (see Genetic sexing for more efficient SIT application). "One of the costliest components of

SIT is rearing," Mr Bourtzis continued. "Why rear females if we do not need them for releases?"

The identification of the white pupae gene facilitates the development of genetic sexing strains to increase the efficiency of the sterile insect technique applications (Image/Photo: R. Aumann and M. Schetelig/Justus-Liebig-University Giessen).

The GSS requires a selectable gene marker, a specific gene that is linked to the sex of the insect and allows the separation of males from females. One selectable marker that has been used for the construction of GSS in some of the most destructive tephritid pest species – *Ceratitis capitata* (Mediterranean fruit fly), *Bactrocera dorsalis* (Oriental fruit fly) and *Zeugodacus cucurbitae* (melon fly) – is the colour of pupae. Pupae are insects in immature form between larvae and adults.

In a recent study by experts of the Joint FAO/IAEA Centre, in collaboration with several research institutions, scientists isolated the white pupae gene responsible for the colour of pupae in tephritids. "The original pupae colour is brown, while mutations in the gene can change the colour from brown to white. This allows the links – the brown pupae colour to males and the white pupae colour to females – and the construction of GSS. Interestingly, the great majority of the insects tested had the white pupae gene, including insect species of SIT importance," Mr Bourtzis said. The isolation of the white pupae gene, in combination with its presence in most insect species, will allow for the faster development of mutant strains that could be used for GSS. As a proof of principle, new strains with the white pupae mutant gene were developed for the Mediterranean fruit fly and the Queensland fruit fly, *Bactrocera tryoni*.

"It is now possible to create such colour variants in new species in a targeted manner. This can be conducted effectively through minimally invasive genome editing and without introducing any foreign genes," said Mr Marc F. Schetelig of the Institute for Insect Biotechnology at Justus-Liebig-University Giessen and co-author of the study. "Bringing this system to new species will expand the reach of SIT programmes and allow for improved and successful area-wide insect pest management."

THE SCIENCE: Genetic sexing for more efficient SIT application

A genetic sexing strain (GSS) is a strain that allows male-only releases for SIT applications. With GSS, a given selectable marker, usually a phenotypic trait, is linked to sex to aid in the sorting process. Some GSS could include more than one marker. The VIENNA 8 strain of the Mediterranean fruit fly carries two selectable markers, the *white pupae* (*wp*) gene and the *temperature sensitive lethal* (*tsl*) gene. Like the *wp* gene, the *tsl* gene is a key marker since it has allowed the linkage of temperature resistance to males and temperature sensitivity to females. When embryos are exposed to elevated temperatures, at 34 or 35 degrees Celsius, only males survive. "In this particular GSS, the white pupae gene allows us to monitor the genetic stability of the sexing system by removing any 'escapers,' such as individuals who have the wrong pupae colour or the wrong *tsl* profile," Mr Bourtzis said. The GSS supports cost effective male-only production and releases for SIT applications, as resources are not spent on rearing and sterilizing females that need to be discarded, thus optimizing mass-production and field implementation.

INSECT DOCTORS Network Meeting, 4–5 October 2021, INRAE Campus Jouy en Josas, France (hybrid in person and virtual)

The INSECT DOCTORS Network meeting was held in a combined form (in person and virtual) on 4–5 October 2021 to review the progress and workplan. Each of the 15 PhD candidates recruited for INSECT DOCTORS presented the progress of their work. Ms Hannah Huditz a consultant in IPCL, as one of the PhD candidates of the INSECT DOCTORS, attended this meeting and made an oral presentation on the progress of her work on the detection of iflavirus and negevirus in tsetse flies.

Participants of the INSECT DOCTORS Network meeting, *4-5th October 2021, INRAE campus Jouy en Josas, France.*

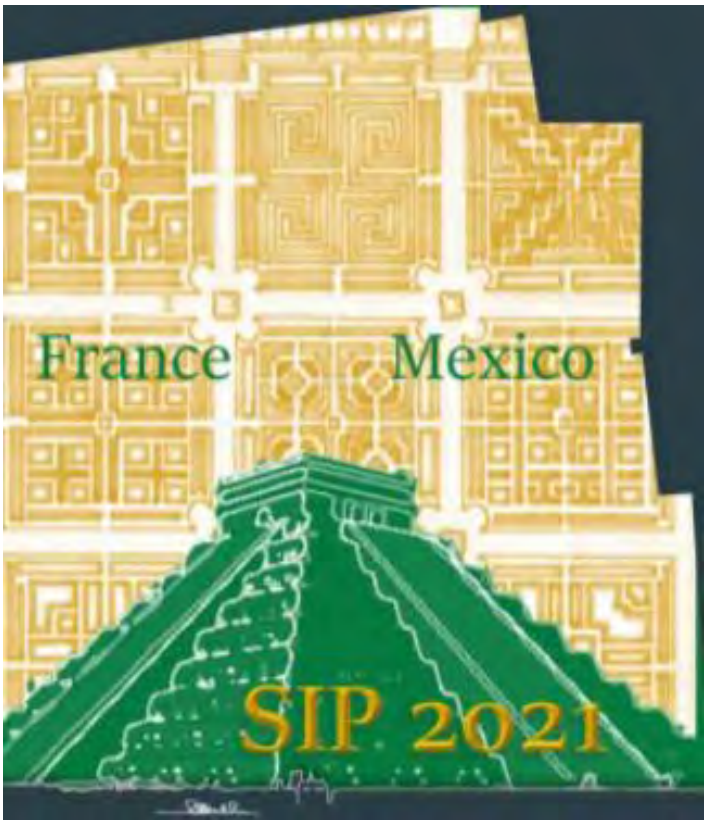
The IPC Subprogramme staff participated in this meeting virtually and made an oral presentation on 'quality control parameters in insect mass-rearing for SIT'. It is worth mentioning that the INSECT DOCTORS is an innovative new European Joint Doctoral Programme (EJD) funded in the framework of the H2020 Marie Skłodowska-Curie ITN programme and aims to train promising young scientists to develop the knowledge, technical skills, and tools to manage

infectious disease problems in commercial insect production systems. The Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture is one of the partner organizations that provide training, materials and/or secondments.

2021 International Congress on Invertebrate Pathology and Microbial Control & 53rd Annual Meeting of the Society for Invertebrate Pathology (virtual meeting), 28 June–2 July 2021 (virtual)

2021 International Congress on Invertebrate Pathology and Microbial Control & 53rd Annual Meeting of the Society for Invertebrate Pathology (SIP) was held virtually in Tours, Loire Valley, France with the participation of LE STUDIUM Loire Valley Institute for Advanced Studies, the French Insect Biology Research Institute (IRBI), the French National Centre for Scientific Research (CNRS), the University of Tours and the University of Guanajuato (Mexico). About 200 researchers in insect pathology, covering microbial, fungal, microsporidia, nematode and viral diseases attended the meeting. Many research papers were presented on insect pest control with special focus on control of the fall armyworm *Spodoptera frugiperda*.

During the conference, IPC Subprogramme staff participated and followed the presentations in the plenary session entitled 'Current challenges for the microbial control of *Spodoptera frugiperda*' and two symposia, a cross-divisional symposium entitled 'Viruses of pollinators' between the Virus and Diseases of Beneficial Invertebrates divisions and a virus division symposium entitled 'Place of Baculovirus in the fight against COVID-19'.



In relation to the SIT, the virome of the Mediterranean fruit fly was presented by Dr Salva Herrero, University of Valencia highlighting the discovery of about 13 new viruses infecting *Ceratitis capitata*. After the SIP meeting, Mr Adly Abdalla from the FAO/IAEA Joint Centre of Nuclear Techniques in Food and Agriculture, attended the Virus Division Business Meeting as a secretary and was nominated and elected as Chair Elect.

Announcements

Call for Research Proposals on a New FAO/IAEA Coordinated Research Project (CRP): Improve the Mass-rearing of Lepidoptera Pests for SIT Programmes

Lepidoptera are key insect pests that require control measures to avoid significant losses in many cropping systems worldwide. The sterile insect technique (SIT), which involves mass-rearing and releasing sterile insects to overflood a wild pest population, has been used successfully against several Lepidoptera pest species such as pink bollworm, codling moth, false codling moth, Australian painted apple moth and cactus moth. The Member States are requesting more technical assistance on SIT application of Lepidoptera pests of economic importance such as those mentioned above and others like the European grapevine moth, African sugarcane stalk borers, navel orangeworm and cocoa pod borer.

However, despite successes, the wider development and deployment of SIT on Lepidoptera pests has important issues that need further investigation. Having an efficient, cost-effective mass-rearing methodology is the backbone of any successful SIT programme. The processes of mass-rearing that require a research focus include: the development and refinement of artificial larval diet(s), the development of protocols for pathogen monitoring and management, identification of methods for marking mass-reared sterile Lepidoptera, the development and optimization of egg collection, processing, sanitation, incubation and diet seeding methods and technologies, diet enhancement through additives such as sterols and cryoprotectants, and increased automation to improve productivity and reduce costs.

A new Coordinated Research Project (CRP) entitled 'Improve the mass-rearing of Lepidoptera pests for SIT programmes' has been initiated and will focus on three areas of mass-rearing for Lepidoptera SIT: (1) develop basic rearing for species that have potential for the SIT but for which no artificial rearing has been developed, (2) scale up rearing technology for species where rearing is possible in small numbers and (3) improve mass-rearing for species under operational programmes.

Overall Objectives:

Expand and improve the sterile insect technique for use against lepidopteran pests of crops to improve food security and enhance health and well-being.

Specific Objectives:

- Establishing basic rearing technologies for Lepidoptera of economic concern.
  - Develop basic rearing technology for candidate pests.
  - Larval diets for rearing Lepidoptera pests.
  - Protocols for pathogen monitoring and management.
- Scaling, and adapting basic rearing technologies to mass-rearing systems for the application of the SIT against lepidopteran pests.
  - Mass-rearing systems for pilot-field and/or commercial scale production.
  - Methods for marking mass-reared sterile Lepidoptera.
  - Handling protocols and packing materials for mass-reared Lepidoptera.
  - Technology for mechanically separating mass-reared male and female moths, particularly for those species with female choice mating systems.
  - Optimize egg collection, processing, sanitation, incubation and diet seeding methods and technology.
  - Document forecast(s) and economic analysis of mass-rearing systems for the application of area wide SIT.
- Optimizing existing mass-rearing systems for sterile Lepidoptera to increase efficacy and reduce the cost of existing area-wide SIT programmes.
  - Refined and optimized larval diets for the more efficient and effective application of existing area wide SIT programmes.
  - Increased automation of mass-rearing processes.
  - Procedures and technology to incorporate diet enhancing additives.

Duration:

The expected duration of the CRP is five years (2022–2027) and the first Research Coordination Meeting is planned for 5–9 September 2022 in Vienna, Austria.

Applications:

Scientist and researchers who are interested in collaborating in this new CRP should contact Mr Daguang Lu (d.lu@iaea.org) or Mr Marc Vreysen (m.vreysen@iaea.org). Information on the IAEA Coordinated Research Programme and how to apply for research contracts and research agreements can be found at http://cra.iaea.org/. Applications should be submitted by 30 April 2022 to research.contracts@iaea.org.

E-learning Course on Action Plan against Quarantine Fruit Fly Species of the Genus *Bactrocera spp.*

The e-learning course is based on the harmonized procedures manual 'Action Plan Against Quarantine Fruit Fly Species of the Genus *Bactrocera spp*.'. It aims at providing the basis for the delimitation of a pest incursion and eradication of outbreaks of fruit fly species that respond to the male specific attractant Methyl Eugenol such as the oriental fruit fly (*Bactrocera dorsalis*) as well as against fruit flies that respond to Cuelure, such as the melon fly (*Zeugodacus*

cucurbitae). The methods and technologies described have been validated and used in action programmes against these fruit fly pests by the National Plant Protection Organizations (NPPOs) of several FAO and IAEA Member States.

The course is divided into four modules, each containing one or more chapters. Furthermore, a list of appendixes containing additional information as well as all references and a glossary of relevant terms is available. The course presents diagrams and videos illustrating how emergency response actions are implemented.

This e-learning course does not have a time limit. You can start the course at any time, take breaks and continue where you have left. The course can be accessed through the IAEA e-learning platform: https://elearning.iaea.org/m2/course/index.php?categoryid=50 (Course only available in Spanish).

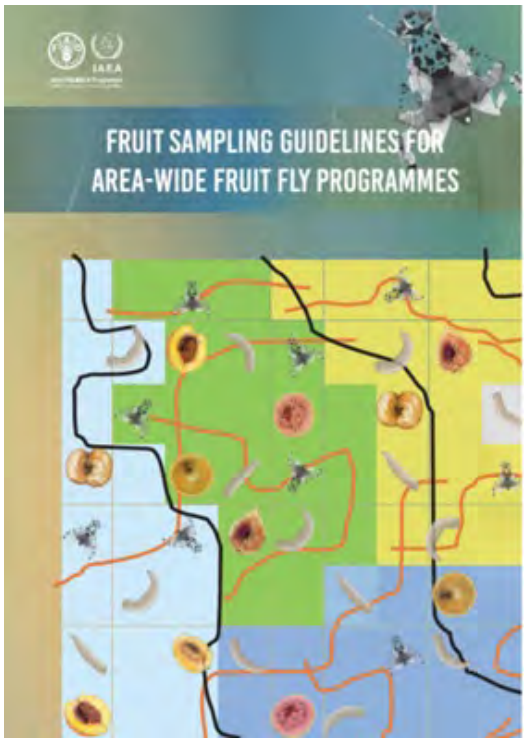
E-learning Course on Fruit Sampling for Area-Wide Fruit Fly Programmes

The e-learning course is based on the guideline 'Fruit Sampling for Area-Wide Fruit Fly Programmes'. It is aimed at providing guidelines to detect the presence or absence of the target fruit fly species in an area. It is also directed to monitor immature stages of the pest to determine those fruits that are hosts as well as fruit fly spatial and temporal distribution and abundance. This information is used by programme managers to plan and implement prevention, suppression or eradication activities.

Fruit sampling can work as a stand-alone pest surveillance tool or it can be complementary to fruit fly trapping. The aim of this e-learning is to understand the principles behind fruit sampling as part of the area-wide fruit fly programme. By successfully completing this course, you will be able to apply the lessons learned in real life operational programmes.

The course is divided into seven modules, each containing one or more chapters. Furthermore, a list of appendixes containing additional information as well as references and needed forms for data recording. The course presents diagrams and videos illustrating how fruit sampling in area-wide fruit fly programmes is implemented.

This e-learning course does not have a time limit. You can start the course at any time, take breaks and continue where you have left.



The course can be accessed through IAEA e-learning platform: https://elearning.iaea.org/m2/course/index.php?categoryid=50.

FAO/IAEA Guidelines for Biosafety and Biosecurity in Mosquito Rearing Facilities (Version 1.0)

This guideline refers to a mosquito rearing facility which is suitable for work with uninfected mosquito vectors including: 1) mosquitoes that are already present in the local geographic region, and 2) exotic mosquitoes that upon escape would be inviable or become only temporarily established in areas not having active vector borne disease transmission.

The guidelines can be downloaded from IPC website at: https://www.iaea.org/sites/default/files/guidelines_for_mosquito_facilities.pdf.

General Guidelines to Facilitate the Opening of International Markets for Fruits and Vegetables that are Fruit Fly Hosts based on International Standards for Phytosanitary Measures

The purpose of the guide is to elaborate on the use of international standards to facilitate international trade of fresh fruit and vegetables known to be fruit fly hosts considering the regulatory framework that is defined by the World Trade Organization (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures (the SPS Agreement) and the International Plant Protection Convention (IPPC) with its associated International Standards for Phytosanitary Measures (ISPMs).

The guideline is also available in Spanish. It can be downloaded from IPC website at: https://www.iaea.org/resources/technical-report/general-guidelines-to-facilitate-the-opening-of-international-markets-for-fruits-and-vegetables-that-are-fruit-fly-hosts-based-on-international-standards-for-phytosanitary-measures.

In Action - Nuclear Applications in Agriculture: On-the-Ground Success, Part V

The Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture uses nuclear and related methods to improve technologies for sustainable agriculture and food security worldwide. It delivers results through adaptive research and development at its own Agriculture and Biotechnology Laboratories as well as through annual support and coordination of more than 25 coordinated research projects involving cooperation with about 400 international and national research institutions and experimental stations; it provides capacity building and technology transfer to over 200 national and regional technical cooperation projects; and it offers technical and policy advice to policy makers.

The application of the Joint FAO/IAEA Centre's innovative technologies supports member countries to meet global challenges, not least towards meeting the challenges of the current COVID-19 pandemic. This and related stories, including four on insect pest control, are highlighted in this biennial publication.

The PDF version can be downloaded from IPC website at: https://www.iaea.org/sites/default/files/cb5847en.pdf.

11th International Symposium on Fruit Flies of Economic Importance

First Announcement

We are pleased to announce the 11th International Symposium on Fruit Flies of Economic Importance to be held from 13–18 November 2022, in Sydney, NSW, Australia. The meeting will be conducted in a hybrid format (presential and virtual).

Since the first symposium in Athens, Greece (1982), the aim of these meetings is to gather scientists, researchers, and those involved in plant protection agencies and phytosanitary operational programs to share their knowledge, technologies and experiences regarding fruit flies. In the past 40 years, these symposia have contributed to the development and improvement of environmental-friendly control methods, management strategies that minimize the negative effects of fruit fly pests worldwide, and the conformation of a very strong and friendly community of tephritidologists.

The symposium program will cover all relevant disciplines ranging from basic knowledge to applied research to program implementation. The following sessions will be considered:

1) Biology, Ecology, Physiology and Behavior

2) Taxonomy and Morphology

3) Genetics and Biotechnology

4) Chemical Ecology and Attractants

5) Risk Assessment, Quarantine and Post-harvest

6) Sterile Insect Technique

7) Natural Enemies and Biological Control

8) Other Control Methods

9) Area-wide Integrated Pest Management and Action Programmes

10) Social, Economic and Policy Issues of Action Programmes

The meeting will be held in English, and all sessions will be held in venue as well as online.

Further information about the symposium can be found at: https://www.11isffei.com/.

Registration fees as well as abstracts and poster guidelines will be available at the website by February 2022.

In Memoriam

Roger J. Wood (1934–2021)

With great sadness we must inform you that Mr. Roger J. Wood, Senior Reader at the Faculty of Science of Manchester University, England, passed away on 15 August 2021.

Roger's extensive career in the research and teaching of insect genetics started in the middle of the last century, after he completed his Ph.D. in mosquito genetics at the London School of Hygiene & Tropical Medicine.

At Manchester University he dedicated much of his professional career to conducting research into mosquito genetics, including meiotic drive and insecticide resistance mechanisms. Here he set up insect breeding laboratories for several insect species. His primary stimulus was to halt the ever-increasing use of pesticides in human health and agriculture, which he saw as increasingly harming the environment and generating pesticide resistance in the targeted insects. In this way he wanted to develop biological means to control these insect pests.

Later, he branched into the Mediterranean fruit fly (medfly), where he conducted studies on genetic sexing mechanisms, sexual behaviour and ways to sterilize males artificially and release them into wild populations. He also participated extensively in the FAO/IAEA's medfly genetic sexing research coordination activities, where his scientific contributions and pioneering work since the early 1980's generated basic and applied knowledge that, along with that of many other scientists and research laboratories, enabled the creation of medfly genetic sexing strains. He was also an active participant of the International Symposia on Fruit Flies of Economic Importance since the formation of this research group in 1982.

With the departure of Roger, we have lost a great scientist and friend. Those who knew Roger will remember him for his friendship, his scientific contributions, his kindness, and his gentleman mindset.

Source: E. Busch-Petersen; J. Cosgrove & P. Rendon.

Patrick Dennis Greany (1943–2021)

With great sadness we must announce the passing away of Patrick Dennis Greany in Gainesville, Florida, the United States of America on 15 September 2021. Pat graduated from Fresno State College and obtained a Ph.D. in Entomology from the University of California at Riverside, where he was named an Outstanding Graduate Student. Upon graduation, he accepted a research position with the USDA laboratory in Gainesville, Florida (now the Center for Medical, Agricultural and Veterinary Entomology). He had an accomplished career researching the biological control of insects, publishing articles in scientific journals and serving on graduate student committees at the University of Florida. He also served one term as the President of the Florida Entomological Society.

During his scientific career, Pat worked on the rearing of *Diachasmimorpha longicaudata*, a fruit fly parasitoid that was then transferred to mass-rearing facilities to be used on the biological control of various fruits flies by integrating with the sterile insect technique (SIT). His broad view on the use of nuclear techniques in biological control, made him a leader in this area of work. Later, Pat worked on the fruit colour preferences and citrus biochemical resistance to Caribbean fruit fly. Towards the end of his career, he focused on the use of gibberellic acid to reduce citrus fruit susceptibility to fruit flies. Upon retirement, Pat moved to Tallahassee and worked part-time in technology transfer for Florida State University and later for the University of Florida.

Other News

Preventive Releases of Sterile Mediterranean Fruit Fly in the Santiago, Metropolitan Region in Chile

In November 1995, Chile declared the country free of the Mediterranean fruit fly, *Ceratitis capitata,* after eradicating the last remaining population of the pest in the city of Arica, in the extreme north of the country. This status allowed the exports of fresh fruit and vegetable to more than 100 countries without using post-harvest treatments. However, Chile faces a high pressure of pest incursions due the heavy movement of people, goods and commodities entering the country from infested areas. For early detection of the pest and rapid response, the National Plant Protection Organization operates a country-wide fruit fly detection system using specific traps and fruit sampling. This surveillance system has allowed Chile to detect the transitory entries of the pest and implemented effective eradication actions including in the urban area of Santiago, in the central zone of the country.

Until 2016, Mediterranean fruit fly outbreaks were eradicated following conventional practice including intensive application of insecticide baits to the tree canopy and insecticide soil drenching under the canopy of the host trees. From that year, Chile began to gradually incorporate the use of sterile insects in the eradication of those outbreaks. A small sterile fly emergence and release facility composed of two containers, with the capacity to handle two million sterile flies was established in the Metropolitan Region of Santiago. The irradiated pupae of *C. capitata* VIENNA-8-TOLIMAN strain was shipped from the Sterile Insect Production Center located at Lluta Valley in Arica, about 2000 km north from Santiago.

In 2019, Chile had to face one of the largest outbreaks so far with a very high eradication cost of approximately US$ 5 million. The eradication strategy involved the sterile insect technique (SIT) by means of the release of sterile flies using a release rate of more than 2 500 sterile males per hectare twice a week, together with the application of insecticide soil drenching achieving the eradication of the outbreak by the end of that year.

Considering the good results of the use of the SIT and the continuous high pest pressure from infested areas outside the country, the Agricultural and Livestock Service of Chile (SAG) decided in 2019 to use the SIT as a prevention control method releasing preventatively sterile male flies over areas at risk of pest entries in the urban area of Santiago as per historical detection data. A new sterile fly emergency and release facility is available where 8 million sterile flies are packed in paper bags each week. The center has the weekly capacity to pack about 14 million sterile pupae in paper bags and 40 million using the chilled adult technique. The sterile fly emergence and release facility in Santiago consists of a system of containers prepared for a conventional system of packaging in paper bags, the emergence of adults, and their release by ground. Additional containers are used to perform quality control tests of the sterile pupae received, as well as to identify recaptured specimen.

Interior of the fly emergency and release facility where the sterile male flies emerge in paper bags before being released in the field (Photo: SAG).

This preventive release programme aims to mitigate possible Mediterranean fruit fly outbreaks in the urban area of Santiago Metropolitan Region. It also supports a rapid response for the eradication of outbreaks detected outside of the preventive release area. An area of about 5 500 hectares in the Metropolitan Region was selected for a preventive release pilot programme using a density of not less than 500 sterile males per hectare twice a week. The programme began its operations in January 2020 and until November 2021 no new outbreaks have been registered in the working area.

In the release areas, paper bags are opened every 2 hectares and a surveillance system is maintained where the traps are checked once a week, additionally in this same area a fruit sampling system is carried out.

The initial results have allowed to consider expanding the area under this strategy of SIT application and also test the incorporation of the chilled adult technique for ground release. In addition, pilot tests are being carried out using drones for aerial sterile fly releases and probably in the near future using airplanes to improve sterile fly distribution.

Release of sterile flies using paper bags in the preventive release area (Photo: SAG).

It should be noted that during 2021, an outbreak of Mediterranean fruit fly was detected outside the preventive release zone located in the western sector of Santiago. The outbreak was successfully eradicated with the release of sterile flies shipped from the mass-rearing facility in Arica, Chile and in Mendoza, Argentina, using two million pupae per week and some conventional control practices. The release densities were not less than 2 500 flying males per hectare, and it was possible to reduce the insecticide soil drench application by 60% compared with the eradication outbreaks without SIT application. The results show an effective suppression and by November 2021, two life cycles of the pest had been completed without new detections which will allow declaration of eradication soon.

Source: Jocelyn Yevenes Flores and Juan Machuca Lagos, (SAG), Chile.

ISCAMEN Expands the Use of the Chilled Adult Release System

In Argentina, actions against the Mediterranean fruit fly by using the sterile insect technique (SIT) are currently carried out in urban areas north and east of Mendoza.

The need to advance to a more ecological and efficient system motivated The Instituto de Sanidad y Calidad Agropecuaria Mendoza (ISCAMEN) to introduce the chilled adult release technique. The inauguration of the Centre for Packing and Distribution of Chilled Adults (CEDAF), in General Alvear, generated a strategic link between the Mediterranean fruit fly pest free and low prevalence areas of Mendoza and Argentina in general.

The introduction of this new technology made the expansion of the Mediterranean fruit fly control programme beyond the Mendoza province limits possible. The chilled adult release technology allowed to get rid of the traditional paper bags and all the inside paper used as adult resting area, further enhancing the sustainability of this environmentally friendly control method.

Furthermore, the evaluation of the results shows a high competitiveness of the release insects, as a result of the better conditions which allow stress reduction as well as a substantial reduction in the operational costs.

Typical chute used in aircraft for chilled adult release.

The Mediterranean fruit flies produced on the ISCAMEN mass-rearing facility, in the Santa Rosa Department, are transported to CEDAF where sterile pupae are placed in containers called 'Emergence Towers'. The facilities and the technology have allowed the release of the sterile flies in Mendoza, but also in other locations in Argentina including all pest free areas in the Patagonia region such as Neuquén, Roca, Cipolletti, Cinco Saltos, Centenario and Allen. This constitutes an innovation in the protection of large areas at national and regional levels.

Given the results obtained, it is expected to expand this national scheme incorporating other new release areas. Following these lines, technicians and professionals from San Luis Ministry of Production, visited ISCAMEN to move towards achieving this objective. The representatives of the Ministry met with professionals of the Mendoza Mediterranean fruit fly eradication programme. The meeting was held in the ISCAMEN headquarters where they visited the identification laboratories and the fruit fly mass rearing facility in Santa Rosa.

With this purpose, a new airplane was recently incorporated to the fleet already available for the application of the chilled adult release system.

Source: MendoVoz, 30 May 2021. https://www.mendovoz.com/actualidad/provinciales/2021/5/30/iscamen-amplia-la-liberacion-de-insectos-esteriles-con-la-tecnica-del-adulto-frio-101084.html?fbclid=IwAR3rQNfdUTL04hhA0yueqUyd1vKyPla-TaC0BFLp8Ch0eeeEhn7XGOQ16tM.

The International Commission on Zoological Nomenclature has Conserved Current Usage of the Generic Name *Anastrepha* Schiner, 1868 by Conditional Reversal of Precedence with Respect to *Toxotrypana* Gerstaecker, 1860

Recent morphological and molecular studies have demonstrated that two genera of *Anastrepha* Schiner, 1868 and *Toxotrypana* Gerstaecker, 1860 are synonyms. According to the rule of the International Commission on Zoological Nomenclature (ICZN), *Toxotrypana* should take precedence and to be used because it is the 'senior synonym', published in 1860 by Gerstaecker, eight years earlier than *Anastrepha* that was published by Schiner in 1868.

However, while only one species of *Toxotrypana* (*T. curvicauda*) is an agricultural pest and the multiple major pest species currently placed in *Anastrepha* have far greater impact on numerous commercial and subsistence fruit crops, if followed with ICZN rules, approx. 300 species in the genus *Anastrepha*, including several species of agricultural importance such as the South American fruit fly *A. fraterculus*, the South American cucurbit fruit fly *A. grandis*, the Mexican fruit fly *A. ludens*, the West Indian fruit fly *A. obliqua* and others should now all be referred to as *Toxotrypana* species. This would cause serious nomenclatural instability and confusion in the applied research field.

Anastrepha curvicauda *formelly known as* Toxotrypana curvicauda *(Photo: bugwood.org).*

To ensure the stability, ICZN used its plenary power to give the name *Anastrepha* Schiner, 1868, precedence over the name *Toxotrypana* Gerstaecker, 1860 whenever the two are considered synonyms (Bulletin of Zoological Nomenclature 78: Opinion 2479 (Case 3772) https://www.iczn.org/cases/resolved-opinion-issued/case/3772).

In practice, this means that nothing changes and the name of *Anastrepha* will be continually used for these species. The only change is the reference to the papaya fruit fly *T. curvicauda*. As *Toxotrypana* is now considered a synonym, reference to this species should in the future be used as *Anastrepha curvicauda*. The same applies to the other six species formerly placed in the genus *Toxotrypana*.

Source: Marc De Meyer, Royal Museum for Central Africa (Tervuren, Belgium).

Fruit Fly Invasion on the Spot: The Horizon 2020 Funded FF-IPM Project Contributes to Prevention, Interception, Detection and Management of New and Emerging Fruit Flies in Europe

The risks of arrival, establishment and range expansion of exotic fruit flies are a global concern. It is expected that the threat of some of the major invasive species, such as *Ceratitis capitata*, *Bactrocera dorsalis*, and *B. zonata* may escalate in the near future because of global climate change, increased trade, and human mobility. In addition, the ban of neonicotinoids, which is one of the main control tools against fruit flies in Europe, poses an additional burden on fruit growers in Europe. To address the European needs (small size, scattered farms operated under diverse socioeconomic and regulatory frameworks), the European Union is funding a project entitled 'FF-IPM: In-silico boosted, pest prevention and off season focused IPM against new and emerging fruit flies' through the Horizon 2020 programme.

This project builds on existing knowledge to identify and fill the critical information gaps. It aims to boost regional fruit fly prevention by developing new, and also enhancing the existing interception and detection tools in order to provide new 'in-silico' assisted Integrated Pest Management (IPM) approaches that will be validated and adapted to European socioeconomic and agricultural conditions. The FF-IPM response toolbox against emerging (*C. capitata*) and new (*B. dorsalis*, *B. zonata*) fruit fly pests is reinforced by a set of novel decision support tools, dedicated and optimized to each of the target species. This is accomplished by a strong group of 21 partners from academia, research institutes and museums, businesses, and growers' organizations. FF-IPM follows a multi-actor approach, with genuine coordinated involvement of relevant actors/stakeholders, and substantive roles envisaged for them and in-built into its work plan.

This four years Project started in 2019 and has recently completed its mid-term review. In the past two years and despite COVID-19 related problems that have hampered some of the activities, it has nevertheless already achieved a number of tangible outputs. Information gaps regarding essential aspects to understand the invasive potential of the target species, such as thermal tolerance, starvation resistance or overwintering capacity were identified, and experimental tests conducted in order to provide answers.

The majority of these experiments are now finalized, and the scientific findings will be published in the near future. For innovative detection tools, the emphasis has been on the development of electronic nose for rapid interception of

infested fruits and electronic traps for a more efficient surveillance and early detection strategy.

Demonstration of the different models of electronic traps in a recent training course organized in Naoussa, Greece by the University of Thessaly, Greece in collaboration with the Agricultural Research Organization of Israel.

Novel diagnostic tools, both using morphological and molecular characteristics have also been developed. In addition, the efficiency of a whole set of IPM tools for off- and early season management, including entomopathogenic nematodes and fungi, and ground dwelling predators has been tested. The main emphasis in the forthcoming months will be on finalizing the above-mentioned tools and methods, and on the development and validation of a dynamic pan-European forecast toolbox allowing early alert and detection, and a decision-support toolbox for off- and on-season precision IPM.

Source: Nikos T. Papadopoulos (University of Thessaly, Department of Agriculture Crop Production and Rural Environment, Greece) and Marc de Meyer (The Royal Museum for Central Africa, Belgium).

Millions of Sterile Flies Dropped from the Sky over City

The skies above metropolitan Adelaide will be filled with up to 20 million sterile fruit flies per week as the Marshall Liberal Government ramps up its spring campaign against the insidious pest. More than 600 million sterile fruit flies have been released during the extensive eradication program to date with over 160 000 homes in the outbreak and suspension areas in Adelaide.

Minister for Primary Industries and Regional Development David Basham said sterile flies are being released from a low flying plane each week between now and the end of the year. “Sterile male fruit flies seek out female fruit flies in outbreak areas, mating with them so they can’t reproduce and therefore breaking the life cycle,” Minister Basham said. “As well as from a plane, our biosecurity officers are releasing up to six million sterile fruit flies in Adelaide each week on the ground.

“We expect fruit flies in the 18 outbreak areas across South Australia to become active again as the weather warms up and the Marshall Liberal Government has been working closely with industry to prepare for our biggest fight against fruit fly.

“The Marshall Liberal Government is using every available weapon in our fight against fruit fly and Sterile Insect Technology plays a key role in our eradication program. “Fruit fly could have a devastating impact on our $1.3 billion horticulture sector vulnerable to the pest which is why we have spent almost $40 million to date to protect the hundreds of businesses and thousands of jobs in the industry across the state. “Overwhelming the wild population with our sterile flies will stop them breeding – and now is the time, before the weather really warms up and the flies become more active.

“More than 400 staff have been baiting and trapping within the fruit fly outbreak areas across the state during these cooler months and working with residents to remove fallen fruit and picking ripe fruit from trees to reduce the numbers of flies and the quantity of fresh produce available to them. “Fruit flies lay their eggs in fruit, the eggs grow into maggots that make the fruit rotten and when it falls to the ground the maggots dig into the soil to finish their life cycle, becoming flies that emerge from the ground to breed again. Enjoying delicious homegrown fruit and vegetables without maggots, and without the need for extra pesticides in your own garden, is something we cannot take for granted in South Australia.

Source: Premier of South Australia website, 3 September 2021, by David Basham (https://www.premier.sa.gov.au/news/media-releases/news/millions-of-sterile-flies-dropped-from-the-sky-over-city).

Funding to Stop Exotic Fruit Fly Island Hopping to Mainland

The Australian federal government has revealed a plan to stop exotic fruit flies island hopping to mainland Australia through the nation's northern archipelago. The northern islands are close to areas containing serious pests and diseases that have not reached Australian mainland.

The Northern Australia Quarantine Strategy (NAQS) will undertake a range of activities to manage the risk of pests, with a particular focus on exotic fruit flies. The new five-year response plan protects industries and communities from the risk of exotic fruit flies entering the mainland through Torres Strait.

Northern Australia is on the frontline of biosecurity to protect Australia from the threat of serious pests and diseases posed by proximity to our northern neighbours. Agriculture and Northern Australia Minister David Littleproud said the northern islands were the nation's biosecurity frontlines.

"Strong Torres Strait biosecurity is important in protecting Australia," Mr Littleproud said. "Risk pathways for pests like exotic fruit flies include traditional trade between Papua New Guinea (PNG) and Torres Strait, and natural pathways such as wind, tide and animal migration." "The nation's most northern fruit fly traps only six kilometres from PNG, located on Boigu Island in Torres Strait, and play a vital role in our fruit fly warning system." The NAQS will work to seasonally eradicate the three exotic fruit fly species that enter the Torres Strait.

"The eradication of exotic papaya fruit fly in 1995 around Cairns cost $38 million at the time and resulted in bans on exports - the cost would likely be doubled in todays' money," Mr Littleproud said. "Through monitoring and surveillance my department and its collaborators also work to protect Australia from other serious pests and diseases right on our doorstep in PNG, such as African swine fever."

Source: Farm Online, 3 August 2021, by Jamieson Murphy (https://www.farmonline.com.au/story/7366603/funding-to-stop-exotic-fruit-fly-island-hoping-to-mainland/).

Preliminary Study on the Current Status of Mediterranean Fruit Fly *Ceratitis capitata* in Iraq

A new record of Mediterranean fruit fly, *Ceratitis capitata* was reported in a citrus orchard of Iraq in 2006 after approximately 60 years absence of this pest in the country since 1947. Although several control methods including chemical pesticides and bait applications were used to manage this pest, it was not successful to eradicate the outbreak and the pest spread rapidly to all citrus and other stone fruits orchards in central and southern regions where the main area of fruit production is in the country.

Oriental persimmon is one of major hosts of Mediterranean fruit fly in Iraq.

Therefore, the sterile insect technique (SIT) is being considered to manage the pest in Iraq. For this reason, preliminary studies on the phenology and population dynamics of medfly in Iraq were investigated by adult trapping and fruit sampling during 2007–2009 and 2014–2015.

According to the studies, the three major hosts of medfly in Iraq are citrus (mainly mandarin), oriental persimmon and apricot and the annual population dynamics correspond to the fruiting phenology of those major hosts.

The results were published in 2018 in European Academic Research (https://www.euacademic.org/UploadArticle/3590.pdf) and in 2020 in Plant Archives (http://www.plantarchives.org/SPL%20ISSUE%2020-2/654__3972-3976_.pdf).

Source: Ayad Al-Taweel, Al-Esraa University College, Baghdad, Iraq.

USDA Celebrates 75 Years of Research Contributions Achieved at the Knipling-Bushland U.S. Livestock Insects Research Laboratory

The U.S. Department of Agriculture's (USDA) Agricultural Research Service (ARS) celebrated today the 75th anniversary of the Knipling-Bushland U.S. Livestock Insects Research Laboratory and its historical contributions to the livestock industry and scientific community.

For 75 years, scientists and supporting staff of the Knipling-Bushland U.S. Livestock Insects Research Laboratory have provided invaluable expertise and research in the field of veterinary entomology in support of ARS National Programs-Food Animal Production, Animal Health, Veterinary, Medical and Urban Entomology, and Food Safety.

The ARS Administrator Dr. Chavonda Jacobs-Young and Congressman Chip Roy provided remarks during the event and highlighted the laboratory's many contributions, including innovative ways to control and eliminate invasive pests on livestock, such as ticks, the New World Screwworm, and blood-feeding flies.

The laboratory (formerly known as the U.S. Livestock Insect Laboratory) was first established in 1946 at the Schwethelm ranch in Kerr County, Texas, from a consolidation of three other laboratories working on screwworm research (Dallas, Uvalde, and Menard). It moved to its current location in Kerrville in 1963. It was not until years later (1988) that it was rededicated and renamed in honor of two ARS scientists, Dr. Edward F. Knipling and Dr. Raymond C. Bushland.

"Knipling and Bushland made a mark in science history with a technique that controlled and led to the eradication of screwworm flies in the United States," said Kim Lohmeyer, research leader and acting laboratory director." Their Sterile Insect Technique is still being used today to eradicate screwworms from Central America and has been used successfully to control other important insect pests such as Mediterranean fruit flies, tsetse flies, mosquitoes, and pink bollworms."

Over the years, the laboratory has collaborated with a diverse group of organizations, universities, beef commodity interest groups, and federal and state government agencies.

Source: USDA ARS News, 8 October 2021. (https://www.ars.usda.gov/news-events/news/research-news/2021/usda-celebrates-75-years-of-research-contributions-achieved-at-the-knipling-bushland-us-livestock-insects-research-laboratory/).

Why Flight Testing is an Important Step in Sterile Insect Technique

Releasing hordes of sterilized male insects for unfruitful mating with females, a process known as the sterile insect technique (SIT), is a proven process for combating many species of pests. Its success depends on sterile males dispersing widely enough to outcompete their wild counterparts and mate with enough females to reduce reproduction of a population.

The SIT has potential against the navel orangeworm (*Amyelois transitella*), a moth whose larvae decimates nut crops and, as its name implies, citrus, but scientists still are trying to figure out whether the idea will fly literally. Researchers in California, where the moth's larvae wreak havoc on almonds, walnuts, and pistachios, have conducted laboratory experiments that have revealed a potential glitch in dispersal ability that needs to be addressed before SIT can be effectively deployed against it. Their analysis is described in a report published in June 2021 in the *Journal of Economic Entomology*.

Releasing millions of sterile insects to interfere with a wild pest population won't work if irradiating the insects also hinders their flight capacity. A new study shows this may be the case with navel orangeworm moths (Amyelois transitella)*, and further fine-tuning will be necessary to build a successful sterile insect technique operation to manage the pest (Photo by Mark Dreiling, Bugwood.org).*

The researchers, led by University of California-Riverside Ph.D. student Joshua Reger, examined the impact on the orangeworm of the same mass-rearing, sterilization, and transportation methods successfully used to combat the pink bollworm (*Pectinophora gossypiella*), a cotton pest. According to the new study, what works on the bollworm is iffy for the orangeworm, because the *modus operandi* seems to negatively impact flight performance, the key to dispersal. The researchers concluded that 'the data from the current study demonstrate a substantial reduction in flight capacity in navel orangeworm, particularly males reared under the current conditions intended for use in a SIT program'.

The complexity and many facets of the research described in the paper testifies to the fact that using SIT successfully is more than a matter of collecting insects, rearing them, and releasing a big bunch into the target area. SIT demands

techniques for mass production of males for release, with output numbering as high as hundreds of millions of individuals weekly. It is a complex process, involving elements that can stress the insects, including irritation, collection with vacuum tubes, and chilling before shipping to the release point.

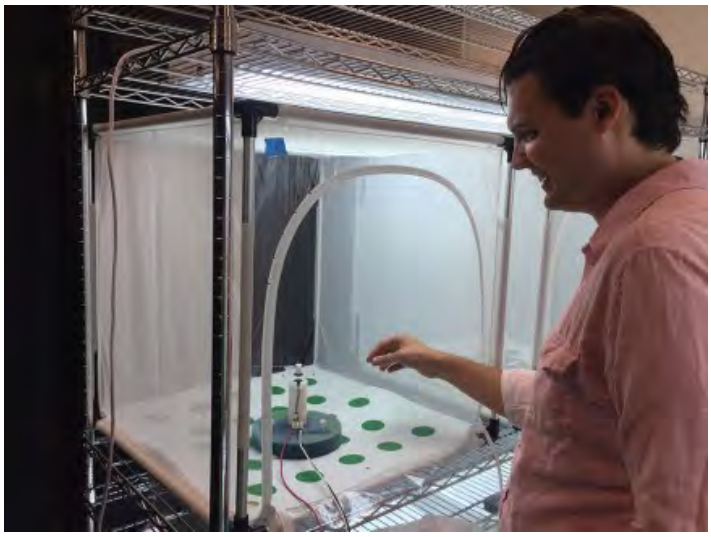
Considerable tinkering with the method is needed before it can be applied to the orangeworm, says Reger. "The mass-rearing, irradiation, transportation, and release processes present various points of stress on navel orangeworm which can negatively affect flight performance," he says. "Going forward, we are excited to examine the different factors such as insect cold tolerance, transportation, and field release method as this work continues."

The study highlights the need for additional research focused on the key features of the SIT process, but this is in tune with other successful SIT programs. Notably, programs aimed at codling moth and pink bollworm were researched and improved over decades, ultimately meeting their goals of pest suppression and eradication, respectively."

The SIT is an ideal solution for dealing with the orangeworm, which has the unique ability to detoxify certain chemical compounds in the environment, including some pesticides. Even if that were not the case, growers are under pressure to use less toxic pest management tools. Major overseas markets for California almonds, pistachios, and walnuts, such as South Korea and the European Union, have strict regulations for pesticide residues. The Almond Board of California is committed to have growers adopt 25 percent more environmentally friendly pest management tools like mating disruption by 2025.

The tasks required to perform the flight-testing experiments used in the study were not for the fumble fingered. Individual moths—at most 11 millimetres long—had to be chilled then glued to a tiny insect pin at the end of an arm of hypodermic tubing on a device called a "flight mill." It resembles a miniature carnival ride, with a thin arm of lightweight tubing that spins while mounted atop a post. The moth is counterbalanced by a dab of painter's putty of the same weight, so each moth in the study had to be individually weighed; most weigh about 7 milligrams. Suspended by magnets and equipped with Teflon bearings, the arm spins so effortlessly it rotates when the moth flies. A sensor records each revolution and thus flight distance.

Reger and his colleagues assessed flight distance in both moths that were mass-reared in the millions and those collected by hand and reared locally in much smaller numbers. Four groups of moths were compared. From a United States Department of Agriculture facility in Phoenix, Arizona, came moths that were irradiated and another batch that was not. Another two were non-irradiated moths that were locally reared at a facility in California, from the Phoenix colony, and a colony that originated in Fresno County, California, in 2011. It turned out, says Reger, that "female moths from both strains are capable of flying similar total distances and durations under all conditions.



The moths' flight capacity is tested using a device called a flight mill, shown here in a netted enclosure. (Photo courtesy of Joshua Reger).

The farthest females flew was up to almost 12 kilometres, while males went for three to more than seven. Mass-reared months had more of what the researchers called "non fliers,' which displayed less than two minutes of continuous flight. Overall, in this study, only males appeared to be negatively influenced by the mass-rearing process. Chilling, which occurs before irradiation and to immobilize moths for attachment to the flight mill, may impact the fitness of males, especially, the study suggests.

As for irradiation, Reger says, "If the irradiation regimen is found to have a large negative impact on insect fitness, there are multiple avenues to explore which may improve it. These include but are not limited to lowering radiation dose, manipulation of atmospheric conditions, changing radiation source, and incorporating radioprotectants into the artificial diet."

Source: Entomology Today, 23 June 2021. By Ed Ricciuti. (https://entomologytoday.org/2021/06/23/flight-mill-testing-important-sterile-insect-technique-navel-orangeworm/).

Drone Tech's Next Big Target: Insect Pest Management

New Research Collection Showcases Unmanned Aircraft Systems' Use Against Mosquitoes, Crop Pests, and More

Drones keep getting smaller and smaller, while their potential applications keep getting bigger and bigger. And now unmanned aircraft systems are taking on some of the world's biggest small problems: insect pests.

From crop-munching caterpillars to disease-transmitting mosquitoes, insects that threaten crops, ecosystems, and public health are increasingly being targeted with new pest-management strategies that deploy unmanned aircraft systems (UAS, or drones) for detection and control. And a variety of these applications are featured in a new special collection published in the Journal of Economic Entomology.

The collection featuring both newly released and recently published research, gathers examples illustrating both the progress and potential of drone technology in insect pest management settings. Case studies include:

- Locating and sampling standing water for mosquito larvae and improving accuracy of insecticide applications targeting mosquito larvae and adults.
- Applying precise amounts of pheromones via drone over cranberry beds to disrupt the mating of cranberry fruitworms (*Acrobasis vaccinii*) and blackheaded fireworms (*Rhopobota naevana*).
- Photographing tree canopies from above via drone in winter to survey for presence of cocoons of the moth *Monema flavescens* and prevent defoliation in the subsequent summer.
- Delivering and releasing predator and parasitoid insects via drone to target the European corn borer (*Ostrinia nubilalis*) and the eastern spruce budworm (*Choristoneura fumiferana*).
- Using drones to release sterile Mexican fruit flies (*Anastrepha ludens*) and codling moths (*Cydia pomonella*) to suppress wild populations of the pests—a modern improvement on the classic sterile insect technique.

Several articles in the collection also explore potential future applications for drone technology in insect pest management, including aerial spectral imagery of crops and plants to assess signs of pest damage, enhanced deployment of traps and monitoring systems to detect insects in hard-to-reach locations, and more.

The Entomological Society of America (ESA) special collection 'Drones to Improve Insect Pest Management' is available now, featuring 15 research articles published in the Journal of Economic Entomology (https://academic.oup.com/jee/pages/drones-to-improve-insect-pest-management).

Source: Entomological Society of America, 28 June 2021. (https://www.entsoc.org/drone-tech-next-big-target-insect-pest-management).

Launch of an SIT Pilot Trial in La Reunion Island

Since 2009, IRD (French Research Institute for Development) and its partners are carrying out a feasibility study on the sterile insect technique (SIT) in Reunion Island, a French overseas department in the southwestern Indian Ocean. Used in addition to other vector control actions, the objective of this environment-friendly method is to reduce the populations of Asian tiger mosquitoes. *Aedes albopictus*, over successive generations, thereby reducing the risk of chikungunya or dengue transmission.

In 2019, a prefectural decree authorized the preliminary release of sterile male mosquitoes in the urban residential area of Duparc (a district of Sainte Marie in Reunion Island, 42ha) to evaluate the dispersal and survival capacity as well as the mating ability of irradiated male *Ae. albopictus* in the urban environment. The results showed that lifespan and dispersal capacity were similar to wild male mosquitoes.

After carrying out this study, the SIT programme progressed to the next step in 2021: following the favorable opinion from the Departmental Commission for the Environment and Health and technological risks on the large-scale application of SIT, a specific prefectural decree authorized the regular releases of sterile males. To do this, a new mass-rearing facility of 84 m², producing currently 200 000 sterile males per week and with a maximum capacity of 5 million sterile males per week, was built and optimized for mass-production with four well equipped rooms (racks and trays, larvae-pupae separator, mass-rearing cages, automatic temperature and humidity control system) dedicated to the different breeding phases.

The sex separation area at the new mass-rearing facility.

The operational pilot phase of the SIT project started in July 2021 with the first release of sterile male mosquitoes. On this occasion, 120 000 sterile male *Ae. albopictus* were released in Duparc. These mosquitoes are produced from a local *Ae. albopictus* strain in the new facility. The pilot phase of the SIT programme aims to demonstrate the effectiveness

of a sustainable approach to control the populations of *Ae. albopictus* by releasing sterile males.

The month of July 2021 was selected for the start of the release campaign because of the relatively low mosquito density during this southern winter season. The release strategy aimed at a ratio of 10 sterile males to 1 wild male in the target area. Sterile males *Ae. albopictus* are released weekly in the pilot areas of 20 ha as part of an integrated suppression strategy that includes door-to-door elimination of breeding sites, and ovitraps coated with Bti deployed at the border of the release area to prevent female immigration. To ensure reasonably good spatial coverage and uniform distribution of the sterile males, the releases are made from the ground in three release points per hectare, taking into account the observed median dispersal distance. In essence, 6 000 sterile males per hectare are ground released weekly in the entire treated zone. The mosquito population is regularly monitored (using weekly ovitrap sampling and monthly BG trapping system) to follow the density of wild *Ae. albopictus* population in comparison with the control site.

Demonstration of the release of sterile males during the lunching of the SIT pilot trial.

The pilot release phase of the SIT programme, fully supported by the European Regional Development Fund and the French Ministry of Health, will be implemented for 12 consecutive months, during which the quantity and quality of sterile males to release will be adjusted according to the observed density and performance, depending on the season. If the effectiveness of the SIT pilot testing is proven at the scale of a district, a large-scale use could be considered by the health authorities for the entire Island, in combination with vector control methods currently in place.

The ongoing SIT project also includes an effective communication strategy both to enhance population support at the pilot area in Duparc and to share research-supported information about SIT to a broad public audience through diverse, engaging, community-oriented activities.

For detailed information please visit the project website: www.tis.re.

Source: Louis Clement Gouagna, IRD, France.

Inauguration of the CTIFL Experimental Tool Dedicated to the Development of the Sterile Insect Technique (SIT)

The French Interprofessional Technical Center for Fruit and Vegetables (CTIFL) inaugurated PiloTis on 8 July 2021, i.e. a new institute dedicated to the development of the sterile insect technique (SIT) at its operational centre of Balandran alongside Aurélie Genholer, regional councillor of Occitania.

On this occasion, Jacques Rouchaussé, president of CTIFL, recalled the beginning of this adventure of dissemination of the SIT in Europe, which started as a Franco-Canadian collaboration during a trip in August 2018. He reaffirmed the ambition of CTIFL to become the European leader in SIT.

Ludovic Guinard, deputy managing director of CTIFL, insisted on the need to transfer this technique as soon as possible to professionals through the efforts of all partners of this project. The goal is to obtain some first results on the codling moth and *Drosophila suzukii* within 1 to 2 years. He stated again CTIFL's objective to provide France with an innovative tool on an industrial scale by ensuring the implementation of a robust and rigorous method. This action can only be achieved with stronger financial support from the French government.

Clélia Oliva, head of the SIT programme at CTIFL and coordinator of the SIT Collective, mentioned the development of SIT in France by presenting the different levers that can help integrate the technique into crop protection strategies.

As for Cara Nelson, former director of the OKSIR programme in Canada, she shared her experience and emphasized the effectiveness of SIT. According to Cara Nelson, the two keys to success after 30 years of experience are communication and teamwork between the different local actors in order to set up the technique.

Source: Fresh Plaza, 15 July 2021 (https://www.freshplaza.com/article/9339452/inauguration-of-the-ctifl-experimental-tool-dedicated-to-the-development-of-the-sterile-insect-technique-sit/).

Relevant Published Articles

Deep Learning Approaches for Challenging Species and Gender Identification of Mosquito Vectors

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Abstract

Microscopic observation of mosquito species, which is the basis of morphological identification, is a time-consuming and challenging process, particularly owing to the different skills and experience of public health personnel. We present deep learning models based on the well-known you-only-look-once (YOLO) algorithm. This model can be used to simultaneously classify and localize the images to identify the species of the gender of field-caught mosquitoes. The results indicated that the concatenated two YOLO v3 model exhibited the optimal performance in identifying the mosquitoes, as the mosquitoes were relatively small objects compared with the large proportional environment image. The robustness testing of the proposed model yielded a mean average precision and sensitivity of 99% and 92.4%, respectively. The model exhibited high performance in terms of the specificity and accuracy, with an extremely low rate of misclassification. The area under the receiver operating characteristic curve was 0.958 ± 0.011, which further demonstrated the model accuracy. Thirteen classes were detected with an accuracy of 100% based on a confusion matrix. Nevertheless, the relatively low detection rates for the two species were likely a result of the limited number of wild-caught biological samples available. The proposed model can help establish the population densities of mosquito vectors in remote areas to predict disease outbreaks in advance.

The full paper was published in: Scientific Reports 2021 11:4838. https://doi.org/10.1038/s41598-021-84219-4.

Invasive Potential of Tropical Fruit Flies In Temperate Regions Under Climate Change

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Abstract

Tropical fruit flies are considered among the most economically important invasive species detected in temperate areas of the United States and the European Union. Detections often trigger quarantine and eradication programs that are conducted without a holistic understanding of the threat posed. Weather-driven physiologically based demographic models are used to estimate the geographic range, relative abundance, and threat posed by four tropical tephritid fruit flies (Mediterranean fruit fly, melon fly, oriental fruit fly, and Mexican fruit fly) in North and Central America, and the European-Mediterranean region under extant and climate change weather (RCP8.5 and A1B scenarios). Most temperate areas under tropical fruit fly propagule pressure have not been suitable for establishment, but suitability is predicted to increase in some areas with climate change. To meet this ongoing challenge, investments are needed to collect sound biological data to develop mechanistic models to predict the geographic range and relative abundance of these and other invasive species, and to put eradication policies on a scientific basis.

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Papers in Peer Reviewed Journals

2021

ABD-ALLA, A.M.M., M.H. KARIITHI and M BERGOIN. (2021). Managing pathogens in insect mass-rearing for the sterile insect technique, with the tsetse fly salivary gland hypertrophy virus as an example, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 317-354.

ARAÚJO, H.R.C., D.O. CARVALHO and M.L. CAPURRO. (2021) *Aedes aegypti* control programmes in Brazil, *In:* Hendrichs J., Pereira R. and Vreysen M.J.B., (Eds.), Area-Wide Integrated Pest Management: Development and Field Application, CRC Press, Boca Raton, FL, USA. pp 339-366.

AUGUSTINOS, A.A., G.A. KYRITSIS, C. CÁCERES and K. BOURTZIS. (2021). Insect symbiosis in support of the sterile insect technique, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 605-630.

BAKHOUM, M.T., M.J.B. VREYSEN and J. BOUYER. (2021) The use of species distribution modelling and landscape genetics for tsetse control, *In:* Hendrichs J., Pereira R. and Vreysen M.J.B., (Eds.), Area-wide Integrated Pest Management: Development and Field Application, CRC Press, Boca Raton, FL, USA. pp 857-868.

BAKRI, A., K. MEHTA and D.R. LANCE. (2021). Sterilizing insects with ionizing radiation, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 355-398.

BALATSOS, G., A. PUGGIOLI, V. KARRAS, I. LYTRA, J. BOUYER et al. (2021). Reduction in egg fertility of *Aedes albopictus* mosquitoes in Greece following releases of imported sterile males. Insects 2021, 12, 110.

BELLINI, R., M. CARRIERI, F. BALESTRINO, A. PUGGIOLI, J. BOUYER et al. (2021) Field competitiveness of *Aedes albopictus* [Diptera: Culicidae] irradiated males in pilot sterile insect technique trials in northern Italy. Journal of Medical Entomology, Volume 58, Issue 2, Pages 807–813.

BELLO-RIVERA, A., R. PEREIRA, W. ENKERLIN, S. BLOEM, K. BLOEM et al. (2021) Successful area-wide programme that eradicated outbreaks of the invasive cactus moth in Mexico, *In:* Hendrichs J., Pereira R. and Vreysen M.J.B., (Eds.), Area-wide Integrated Pest Management: Development and Field Application, CRC Press, Boca Raton, FL, USA. pp 561-580.

BENAVENTE-SÁNCHEZ, D., J. MORENO-MOLINA and R. ARGILÉS-HERRERO. (2021) Prospects for remotely piloted aircraft systems in area-wide integrated pest management programmes, *In:* Hendrichs J., Pereira R. and Vreysen M.J.B., (Eds.), Area-wide Integrated Pest Management: Development and Field Application, CRC Press, Boca Raton, FL, USA. pp 903-916.

BOURTZIS, K., M.J.B. VREYSEN (2021). Sterile Insect Technique (SIT) and its applications. Insects 12, 638.

BOUYER, J., J.ST.H. COX, L. GUERRINI, R. LANCELOT, M.J.B. VREYSEN et al. (2021). Using geographic information systems and spatial modelling in area-wide integrated pest management programmes that integrate the sterile insect technique, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 703-730.

CECILIA, H., S. ARNOUX, S. PICAULT, M. VREYSEN, J. BOUYER et al. (2021). Dispersal in heterogeneous environments drives population dynamics and control of tsetse flies. Proc. R. Soc. B 288: 20202810.

CHAILLEUX, A., D.S. THIAO, S. DIOP, S. AHMAD, C. CACERES et al. (2021). Understanding *Bactrocera dorsalis* trapping to calibrate area-wide management. Journal of Applied Entomology 145(9):831-840.

DE BEER, C.J., A.H. DICKO, J. NTSHANGASE, J. BOUYER, M.J.B. VREYSEN et al (2021). A distribution model for *Glossina brevipalpis* and *Glossina austeni* in Southern Mozambique, Eswatini and South Africa for enhanced area-wide integrated pest management approaches. PLoS Neglected Tropical Diseases. PLoS Neglected Tropical Diseases 15(11):e0009989.

DEMIRBAS-UZEL, G., A.A. AUGUSTINOS, A.G. PARKER, K. BOURTZIS, A.M.M. ABD-ALLA et al. Interactions between tsetse endosymbionts and *Glossina pallidipes* salivary gland hypertrophy virus in heterologous *Glossina* hosts. Frontiers in Microbiology 12:653880.

DIAS V.S., C. CACERES, A. PARKER, R. PEREIRA, U. GULER-DEMIRBAS, A.M.M. ABD-ALLA et al. (2021). Mitochondrial superoxide dismutase overexpression and low oxygen conditioning hormesis improve the performance of irradiated sterile males. Scientific Reports 11:20182.

DOUCHET, L., M. HARAMBOURE, T. BALDET, G. L'AMBERT, J. BOUYER et al. (2021). Comparing sterile male releases and other methods for integrated control of the tiger mosquito in temperate and tropical climates. Scientific Reports 11, 7354.

DOWELL, R.V., J. WORLEY, P.J. GOMES, P. RENDÓN and R. ARGILÉS HERRERO. (2021). Supply, emergence, and release of sterile insects, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 441-484.

DROSOPOULOU, E., A. DAMASKOU, A. MARKOU, A. A. AUGUSTINOS, K. BOURTZIS et al. (2021). The complete mitochondrial genomes of *Ceratitis rosa* and *Ceratitis quilicii*, members of the *Ceratitis* FAR species complex (Diptera: Tephritidae). Mitochondrial DNA B 6: 1039-1041.

DYCK, V.A., E.E. REGIDOR FERNÁNDEZ, B.N. BARNES, J. REYES FLORES, D. LINDQUIST et al. (2021). Communication and stakeholder engagement in area-wide pest management programmes that integrate the sterile insect technique, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 815-840.

DYCK, V.A., J. REYES FLORES, M.J.B. VREYSEN, E.E. REGIDOR FERNÁNDEZ, D. LINDQUIST et al. (2021). Management of area-wide pest management programmes that integrate the sterile insect technique, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 781-814.

ENKERLIN, W.R. (2021). Impact of fruit fly control programmes using the sterile insect technique, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 979-1006.

FELDMANN, U., V.A. DYCK, R.C. MATTIOLI, J. JANNIN and M.J.B. VREYSEN. (2021). Impact of tsetse fly eradication programmes using the sterile insect technique, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 1051-1080.

FRANZ, G., K. BOURTZIS and C. CÁCERES. (2021). Practical and operational genetic sexing systems based on classical genetic approaches in fruit flies, an example for other species amenable to large-scale rearing for the sterile insect technique, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 575-604.

GATO, R., Z. MENENDEZ, E. PRIETO, R. ARGILES, J. BOUYER, et al. (2021). Sterile insect technique: successful suppression of *Aedes Aegypti*. Field Population in Cuba. Insects 12, 469.

GIMONNEAU, G., R. OUEDRAOGO, E. SALOU, J.B. RAYAISSE, J. BOUYER et al. (2021) Larviposition site selection mediated by volatile semiochemicals in *Glossina palpalis gambiensis*. Ecol Entomol, 46: 301-309.

GIUSTINA, P.D., T. MASTRANGELO, S. AHMAD, G. MASCARIN, C. CACERES. (2021) Determining the sterilization doses under hypoxia for the novel black pupae genetic sexing strain of *Anastrepha fraterculus* (Diptera, Tephritidae). Insects, 12, 308.

GÓMEZ-SIMUTA Y., A. PARKER, C. CÁCERES, M.J.B. VREYSEN, H. YAMADA (2021). Characterization and dose-mapping of an X-ray blood irradiator to assess application potential for the sterile insect technique (SIT), Applied Radiation and Isotopes, 176, 109859,

HÄCKER, I., K. BOURTZIS and M.F. SCHETELIG. (2021). Applying modern molecular technologies in support of the sterile insect technique, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 657-702.

HENDRICHS, J. and A.S. ROBINSON. (2021). Prospects for the future development and application of the sterile insect technique, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 1119-1170.

HENDRICHS, J., M.J.B. VREYSEN, W.R. ENKERLIN and J.P. CAYOL. (2021). Strategic options in using sterile insects for area-wide integrated pest management, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 841-884.

HENDRICHS, J., W.R. ENKERLIN and R. PEREIRA. (2021). Invasive insect pests: challenges and the role of the sterile insect technique in their prevention, containment, and eradication, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 885-922.

KLASSEN, W. and M.J.B. VREYSEN. (2021). Area-wide integrated pest management and the sterile insect technique, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 75-112.

KLASSEN, W., C.F. CURTIS and J. HENDRICHS. (2021). History of the sterile insect technique, *In*: Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 1-44.

KOSKINIOTI, P., A.A. AUGUSTINOS, D.O. CARVALHO, R. ARGILES-HERRERO, K. BOURTZIS et al. (2021). Genetic sexing strains for the population suppression of the mosquito vector *Aedes aegypti*. Philosophical Transactions Royal Society B 376:20190808.

LEES, R.S., D.O. CARVALHO and J. BOUYER. (2021). Potential impact of integrating the sterile insect technique into the fight against disease-transmitting mosquitoes, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 1081-1118.

LI, Y., L.A. BATON, D. ZHANG, J. BOUYER, A.G. PARKER et al. (2021). Reply to: Issues with combining incompatible and sterile insect techniques. Nature 590**,** E3–E5.

MAMAI, W., H. MAIGA, N.S. BIMBILE SOMDA, T. WALLNER, O.B. MASSO, H. YAMADA, J. BOUYER et al. (2021). Does TapWater Quality Compromise the Production of *Aedes* Mosquitoes in Genetic Control Projects? Insects 12, 57.

MANGAN, R.L. and J. BOUYER. (2021). Population suppression in support of the sterile insect technique, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 549-574.

MARINA, C.F., J.G. BOND, K. HERNÁNDEZ-ARRIAGA, D.O. CARVALHO, K. BOURTZIS et al. (2021). Population dynamics of *Aedes aegypti* and *Aedes albopictus* in two rural villages in southern Mexico: baseline data for an evaluation of the sterile insect technique. Insects 12, 58.

MASTRANGELO, T., A. KOVALESKI, B. MASET, M.D.L.Z. COSTA, C. CACERES et al. (2021). Improvement of the mass-rearing protocols for the south american fruit fly for application of the sterile insect technique. Insects 12, 622.

MEKI I.K., H.I. HUDITZ, A. STRUNOV, R. VAN DER VLUGT, A.M.M. ABD-ALLA et al (2021). Characterization and tissue tropism of newly identified iflavirus and negevirus in tsetse flies *Glossina morsitans morsitans*. Viruses 13, 2472.

NIKOLOULI, K., F. SASSU, C. STAUFFER, C. CÁCERES, K. BOURTZIS et al. (2021). *Enterobacter sp.* AA26 as a protein source in the larval diet of *Drosophila suzukii*. Insects 12, 923.

OLIVA, C.F., M.Q. BENEDICT, C.M. COLLINS, T. BALDET, J. BOUYER et al. (2021). Sterile Insect Technique (SIT) against *Aedes* Species Mosquitoes: A Roadmap and Good Practice Framework for Designing, Implementing and Evaluating Pilot Field Trials. Insects 12, 191.

PARKER, A.G., M.J.B. VREYSEN, J. BOUYER and C.O. CALKINS. (2021). Sterile insect quality control/assurance, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 399-440.

PARKER, A.G., W. MAMAI and H. MAIGA. (2021). Mass-rearing for the sterile insect technique, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 283-316.

PEREIRA, R., B. YUVAL, P. LIEDO, P.E.A. TEAL, J. HENDRICHS et al. (2021). Improving post-factory performance of sterile male fruit flies in support of the sterile insect technique, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 631-656.

RAMIREZ-SANTOS, E.; P. RENDON, G. GOUVI, K. BOURTZIS, C. CACERES et al. (2021). A novel genetic sexing strain of *Anastrepha ludens* for cost-effective sterile insect technique applications: improved genetic stability and rearing efficiency. Insects 12, 499.

RENDÓN, P. and W. ENKERLIN. (2021) Area-wide fruit fly programmes in Latin America, *In:* Hendrichs J., Pereira R. and Vreysen M.J.B., (Eds.), Area-Wide Integrated Pest Management: Development and Field Application, CRC Press, Boca Raton, FL, USA. pp 161-196.

ROBINSON, A.S. (2021). Genetic basis of the sterile insect technique, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 143-162.

SASSÙ, F., T. BAKHOUM, J. BOUYER, C. CÁCERES (2021). Mating competitiveness of sterile male *Drosophila suzukii* under different atmosphere conditions. Proceedings 68.

SASSÙ, F., K. NIKOLOULI, C. STAUFFER, K. BOURTZIS and C. CÁCERES-BARRIOS. (2021) Sterile insect technique and incompatible insect technique for the integrated *Drosophila suzukii* management. *In:* Flávio Roberto Mello Garcia (ed.), *Drosophila suzukii* management. Springer. pp 169-194.

SAVINI, G., F. SCOLARI, L. OMETTO, O. ROTA-STABELLI, A. M. M. ABD-ALLA et al. Viviparity and habitat restrictions may influence the evolution of male reproductive genes in tsetse fly (*Glossina*) species. BMC Biol 19, 211.

SHERENI, W., L. NEVES, R. ARGILÉS, L. NYAKUPINDA AND G. CECCHI. (2021). An atlas of tsetse and animal African trypanosomiasis in Zimbabwe. Parasites Vectors 14, 50.

SON J.H., B.L. WEISS, Ks. M. DERA, F. GSTOTTENMAYER, A.M.M. ABD-ALLA et al. (2021). Infection with endosymbiotic Spiroplasma disrupts tsetse (*Glossina fuscipes fuscipes*) metabolic and reproductive homeostasis. PLoS Pathogy 17(9), e1009539.

TAIT G., S. MERMER, D. STOCKTON, J. LEE, F. SASSU et al. (2021). *Drosophila suzukii* (Diptera: Drosophilidae): A Decade of Research Towards a Sustainable Integrated Pest Management Program. Journal of Economic Entomology, 114(5), 1950–1974.

TUR, C., D. ALMENAR, S. BENLLOCH-NAVARRO, R. ARGILÉS-HERRERO, M. ZACARÉS ET AL. (2021). Sterile insect technique in an integrated vector management program against tiger mosquito *Aedes albopictus* in the Valencia region (Spain): operating procedures and quality control parameters. Insects, 12, 272.

VILJOEN, G.J., R. PEREIRA, M.J.B. VREYSEN, G. CATTOLI, M. GARCIA PODESTA (2021). Agriculture: improving livestock production, *In:* Greenspan E. (Ed.), Encyclopedia of Nuclear Energy, Elsevier, Amesterdam, Netherlands. Vol.4, pp. 302-312.

VREYSEN, M.J.B. (2021). Monitoring sterile and wild insects in area-wide integrated pest management programmes, *In:* Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., CRC Press, Boca Raton, FL, USA. pp 485-528.

VREYSEN, M.J.B., A.M.M. ABD-ALLA, K. BOURTZIS, J. BOUYER, C. CACERES, C. DE BEER, D. OLIVEIRA CARVALHO, H. MAIGA, W. MAMAI, K. NIKOLOULI, H. YAMADA, and R. PEREIRA. (2021). The Insect pest control laboratory of the joint FAO/IAEA programme: ten years (2010–2020) of research and development, achievements and challenges in support of the sterile insect technique. Insects, 12, 346.

VREYSEN, M.J.B., M.T. SECK, B. SALL, A.G. MBAYE, J. BOUYER et al. (2021). Area-wide integrated management of a *Glossina palpalis gambiensis* population from the niayes area of Senegal: A review of operational research in support of a phased conditional approach, *In:* Hendrichs J., Pereira R. and Vreysen M.J.B., (Eds.), Area-wide Integrated Pest Management: Development and Field Application, CRC Press, Boca Raton, FL, USA. pp 275-304.

WARD, C., K. NIKOLOULI, G. GOUVI, C. CÁCERES-BARRIOS, K. BOURTZIS et al. (2021). White pupae phenotype of tephritids is caused by parallel mutations of a MFS transporter. Nature Communications 12:491.

ZHANG D., S. CHEN, A.M.M. ABD-ALLA, K. BOURTZIS (2021). The effect of radiation on the gut bacteriome of *Aedes albopictus*. Frontiers in Microbiology 12:671699.

2020

AUGUSTINOS, A.A., M. UL HAQ, D.O. CARVALHO, L. DURAN DE LA FUENTE, K. BOURTZIS et al. (2020). Irradiation induced inversions suppress recombination among the M locus and morphological markers in *Aedes aegypti*. BMC Genetics 21(Suppl. 2):142.

BAKRI, A., W. ENKERLIN, R. PEREIRA, J. HENDRICHS, E. BUSTOS-GRIFFIN et al. (2020). Tephritid-related databases: TWD, IDIDAS, IDCT, DIR-SIT. In: D. Pérez-Staples, F. Díaz-Fleischer, P. Montoya and M.T. Vera (Eds.). Area-wide Management of Fruit Fly Pests. CRC Press, Boca Raton, FL, USA pp. 369-384.

BAYEGA, A., H. DJAMBAZIAN, K.T. TSOUMANI, M.E. GREGORIOU, K. BOURTZIS et al. (2020). *De novo* assembly of the olive fruit fly (*Bactrocera oleae*) genome with linked-reads and long-read technologies minimizes gaps and provides exceptional Y chromosome assembly. BMC Genomics 21(1):259.

BOURTZIS, K., C. CÁCERES and M.F. SCHETELIG (2020). Joint FAO/IAEA Coordinated research project on "Comparing rearing efficiency and competitiveness of sterile male strains produced by genetic, transgenic or symbiont-based technologies". BMC Genetics 21(Suppl. 2):148.

BOUYER, J. (2020). *Glossina palpalis gambiensis* (Tsetse Fly). Trends in Parasitology 36:864-865.

BOUYER, J., H. YAMADA, R. PEREIRA, K. BOURTZIS, M.J.B. VREYSEN (2020). Phased conditional approach for mosquito management using sterile insect technique. Trends in Parasitology 36:325-336.

BOUYER, J., M.J.B. VREYSEN (2020). Yes, irradiated sterile male mosquitoes can be sexually competitive! Trends in Parasitology 36:877-880.

BOUYER, J., N.J. CULBERT, R. ARGILES HERRERO, H. YAMADA, M. J. B. VREYSEN et al. (2020). Field performance of sterile male mosquitoes released from an uncrewed aerial vehicle, Science Robotics 43(5):eaba6251.

BUSTOS-GRIFFIN, E., G.J. HALLMAN, A. BAKRI AND W. ENKERLIN (2020). International database on commodity tolerance (IDCT). In: D. Pérez-Staples, F. Díaz-Fleischer, P. Montoya and M.T. Vera (Eds.). Area-Wide Management of Fruit Fly Pests. CRC Press, Boca Raton, FL, USA pp. 161-168.

CANCINO, J., A. AYALA, S. OVRUSKI, L. RIOS, J. HENDRICHS et al. (2020). *Anastrepha ludens* (Loew) (Diptera: Tephritidae) larvae irradiated at higher doses improve the rearing of two species of native parasitoids. Journal of Applied Entomology 144:866-876.

CARVALHO, D.O., J. TORRES-MONZON, P. KOSKINIOTI, G. PILLWAX, K. BOURTZIS et al. (2020). *Aedes aegypti* lines for combined sterile insect technique and incompatible insect technique applications: the importance of host genomic background. Entomologia Experimentalis et Applicata 168:560-572.

CHEN, S., D. ZHANG, A.A. AUGUSTINOS, V. DOUDOUMIS, K. BOURTZIS et al. (2020). Multiple factors determine the structure of bacterial communities associated with *Aedes albopictus* under artificial rearing conditions. Frontiers in Microbiology 11:605.

CULBERT, N.J., H. MAIGA, W. MAMAI, H. YAMADA, J. BOUYER et al. (2020). A rapid quality control test to foster the development of the sterile insect technique against *Anopheles arabiensis*. Malaria Journal 19:44.

CULBERT, N.J., M. KAISER, N. VENTER, M.J.B. VREYSEN, J. BOUYER et al. (2020). A standardised method of marking male mosquitoes with fluorescent dust. Parasites & Vectors 13:192.

DE BEER, C.J., MOYABA, S.N.B. BOIKANYO, D. MAJATLADI, M.J.B. VREYSEN et al. (2020). Gamma irradiation and male *Glossina austeni* mating performance. Insects 11:522.

DE COCK, M., M. VIRGILIO, P. VANDAMME, K. BOURTZIS, M. DE MEYER et al. (2020). Comparative microbiomics of tephritid frugivorous pests (Diptera: Tephritidae) from the field: a tale of high variability across and within species. Frontiers in Microbiology 11:1890.

DIAS, V.S., G.J. HALLMAN, A.A.S. CARDOSO, C.E. CÁCERES-BARRIOS, M.J.B VREYSEN et al. (2020). Relative tolerance of three morphotypes of the *Anastrepha fraterculus* Complex (Diptera: Tephritidae) to cold phytosanitary treatment. Journal of Economic Entomology 113(3):1176-1182.

DIAS, V.S., G.J. HALLMAN, O.Y. MARTÍNEZ-BARRERA, N.V. HURTADO, A.A.S. CARDOSO, A.G. PARKER, L.A. CARAVANTES, C. RIVERA, A.S. ARAÚJO, F. MAXWELL, C.E. CÁCERES-BARRIOS, M.J.B VREYSEN, S.W. MYERS (2020). Modified atmosphere does not reduce the efficacy of phytosanitary irradiation doses recommended for tephritid fruit flies. Insects 11:371.

GUISSOU, E., S. PODA, H. MAIGA, J. GILLES, J. BOUYER et al. (2020). Effect of irradiation on the survival and susceptibility of female *Anopheles arabiensis* to natural isolates of *Plasmodium falciparum*. Parasites Vectors 13:266.

HARAMBOURE, M., P. LABBE, T. BALDET, D. DAMIENS, J. BOUYER et al. (2020). Modelling the control of *Aedes albopictus* mosquitoes based on sterile males release techniques in a tropical environment. Ecological Modelling 424:109002.

HIEN, N.T.T., V.T.T. TRANG, V.V. THANH, H.K. LIEN, R. PEREIRA et al. (2020). Fruit fly area-wide integrated pest management in dragon fruit in Binh Thuan Province, Viet Nam. In: D. Pérez-Staples, F. Díaz-Fleischer, P. Montoya and M.T. Vera (Eds.). Area-wide Management of Fruit Fly Pests. CRC Press, Boca Raton, FL, USA p. 343-348.

KOSKINIOTI, P., E. RAS, A.A. AUGUSTINOS, C. CACERES, K. BOURTZIS et al. (2020). Manipulation of insect gut microbiota towards theimprovement of *Bactrocera oleae* articial rearing. Entomologia Experimentalis et Applicata 168:523-540.

KOSKINIOTI, P., E. RAS, A.A. AUGUSTINOS, C. CÁCERES, K. BOURTZIS et al. (2020). The impact of fruit fly gut bacteria on the rearing of the parasitic wasp, *Diachasmimorpha longicaudata*. Entomologia Experimentalis et Applicata 168:541-559.

LAROCHE, L., S. RAVEL, T. BALDET, A.G. PARKER, J. BOUYER et al. (2020). Boosting the sterile insect technique with pyriproxyfen increases tsetse flies *Glossina palpalis gambiensis* sterilization in controlled conditions. Scientific Reports 10:9947.

LEUNG, K., E. RAS, B. KIM, K. BOURTZIS, P. KOSKINIOTI et al. (2020). Next generation biological control: the need for integrating genetics and genomics. Biological Reviews 95:1838-1854.

LIEDO, P., W. ENKERLIN and J. HENDRICHS. (2020). La técnica del insecto estéril*: In:* Montoya, P., Toledo, J. and Hernandez, E., (Eds.), Moscas das Frutas: Fundamentos y Procedimientos para su Manejo, Sy G editors, Ciudad de Mexico, Mexico. Pp 357-374.

LIN, J., H. YAMADA, N. LU, G. AO, W. YUAN et al. (2020). Quantification and Impact of Cold Storage and Heat Exposure on Mass Rearing Program of *Bactrocera dorsalis* (Diptera:Tephritidae) Genetic Sexing Strain. Insects 11:821.

MAIGA, H., J.R.L. GILLES, R.S. LEES, H. YAMADA. and J. BOUYER (2020). Demonstration of resistance to satyrization behavior in *Aedes aegypti* from La Réunion island. Parasite 27:22.

MAIGA, H., W. MAMAI, N.S. BIMBILE SOMDA, T. WALLNER, R. ARGILES-HERRERO, H. YAMADA, J. BOUYER et al. (2020). Assessment of a novel adult mass-rearing cage for *Aedes albopictus* (Skuse) and *Anopheles arabiensis* (Patton). Insects 11:801.

MANGAN, R.L. and W. ENKERLIN. (2020). El enfoque de sistemas em programas de seguridad cuarentenaria*: In:* Montoya, P., Toledo, J. and Hernandez, E., (Eds.), Moscas das Frutas: Fundamentos y Procedimientos para su Manejo, Sy G editors, Ciudad de Mexico, Mexico. Pp 333-340.

MAMAI, W., H. MAIGA, N.S. BIMBILE SOMDA, H. YAMADA, J. BOUYER et al. (2020). *Aedes aegypti* larval development and pupal production in the FAO/IAEA mass-rearing rack and factors influencing sex sorting efficiency. Parasite 27:43.

MEZA, J.S., K. BOURTZIS, A. ZACHAROPOULOU, A. GARIOU-PAPALEXIOU and C. CÁCERES (2020). Development and characterization of a pupal-colour based genetic sexing strain of *Anastrepha fraterculus sp. 1* (Diptera: Tephritidae). BMC Genetics 21(Suppl. 2):134.

MIRIERI, C.K., A.G. PARKER, M.J.B. VREYSEN, J. BOUYER, A.M.M. ABD-ALLA et al. (2020). A new automated chilled adult release system for the aerial distribution of sterile male tsetse flies. PLoS ONE 15:e0232306.

MULANDANE, F.C., L.P. SNYMAN, D.R.A. BRITO, J. BOUYER, J. FAFETINE et al. (2020). Evaluation of the relative roles of the Tabanidae and Glossinidae in the transmission of trypanosomosis in drug resistance hotspots in Mozambique. Parasites & Vectors 13:219.

NIGNAN, C., A. NIANG, H. MAIGA, S.P. SAWADOGO, B.S. PODA et al. (2020). Comparison of swarming, mating performance and longevity of males *Anopheles coluzzii* between individuals fed with different natural fruit juices in laboratory and semi-field conditions. Malaria Journal 19:173.

NIKOLOULI, K., F. SASSU, L. MOUTON, C. STAUFFER and K. BOURTZIS (2020). Combining sterile and incompatible insect techniques for the population suppression of *Drosophila suzukii*. Journal of Pest Science 93:647-661.

NIKOLOULI, K., A.A. AUGUSTINOS, P. STATHOPOULOU, E. ASIMAKIS, K. BOURTZIS et al. (2020). Genetic structure and symbiotic profile of worldwide natural populations of the Mediterranean fruit fly, *Ceratitis capitata*. BMC Genetics 21(Suppl. 2):128.

PERRIN, A., A. GOSSELIN-GRENET, M. ROSSIGNOL, C. GINIBRE1, J. BOUYER et al. (2020). Variation in the susceptibility of urban *Aedes* mosquitoes infected with a densovirus. Scientific Reports 10:18654.

PORRAS, M.F., J.S. MEZA, E.G. RAJOTTE, K. BOURTZIS and C. CÁCERES-BARRIOS (2020). Improving the phenotypic properties of the *Ceratitis capitata* (Diptera: Tephritidae) temperature sensitive lethal genetic strain in support of sterile insect technique applications. Journal of Economic Entomology 113(6):2688-2694.

SALCEDO BACA, D., G. TERRAZAS GONZÁLES, J.R. LOMELI FLORES, E. RODRÍGUEZ LEYVA and W. ENKERLIN. (2020). Evaluación de la Campaña Nacional Contra Moscas de la Fruta (CNMF) *Anastrepha* spp., en seis estados de la República Mexicana (1994-2008). *In:* Montoya, P., Toledo, J. and Hernandez, E., (Eds.), Moscas das Frutas: Fundamentos y Procedimientos para su Manejo, Sy G editors, Ciudad de Mexico, Mexico. Pp 37-58.

SALGUEIRO, J., L.E. PIMPER, D.F. SEGURA, F.H. MILLA, K. BOURTZIS et al. (2020). Gut bacteriome analysis of *Anastrepha fraterculus sp. 1* during the early steps of laboratory colonization. Frontiers in Microbiology 11:570960.

TANG, Z., H. YAMADA, M.J.B. VREYSEN, J. BOUYER, A.M.M. ABD-ALLA et al. (2020). High sensitivity of one-step real-time reverse transcription quantitative PCR to detect low virus titers in large mosquito pools. Parasites Vectors 13:460.

YAMADA, H., H. MAIGA, N.S. BIMBILE SOMDA, J. BOUYER et al. (2020). The role of oxygen depletion and subsequent radioprotective effects during irradiation of mosquito pupae in water. Parasites & Vectors 13:198.

ZHANG, D., Z. XI, Y. LI, X. WANG, H. YAMADA et al. (2020). Toward implementation of combined incompatible and sterile insect techniques for mosquito control: optimized chilling conditions for handling *Aedes albopictus* male adults prior to release. PLoS Neglected Tropical Diseases 14(9):e0008561.

2019

ASIMAKIS, E.D., P. STATHOPOULOU, C. CACERES, K. BOURTZIS, G. TSIAMIS et al. (2019). The effect of diet and radiation on the bacterial symbiome of the melon fly, *Zeugodacus cucurbitae* (Coquillett). BMC Biotechnology 19(Suppl. 2):88.

ATTARDO, G.M., A.M.M. ABD-ALLA, A. ACOSTA-SERRANO, K. BOURTZIS, A.G. PARKER et al. (2019). Comparative genomic analysis of six *Glossina* genomes, vectors of African trypanosomes. Genome Biology 20:187.

AUGUSTINOS, A.A., C.A. MORAITI, E. DROSOPOULOU, I. KOUNATIDIS, K. BOURTZIS et al. (2019). Old residents and new arrivals of *Rhagoletis* species in Europe. Bulletin of Entomological Research 109:701-712.

AUGUSTINOS, A.A., G. TSIAMIS, C. CÁCERES, A.M.M. ABD-ALLA and K. BOURTZIS (2019). Taxonomy, diet, and developmental stage contribute to the structuring of gut-associated bacterial communities in tephritid pest species. Frontiers in Microbiology 10:2004.

AZIS, K., I. ZERVA, P. MELIDIS, C. CACERES, K. BOURTZIS et al. (2019). Biochemical and nutritional characterization of the medfly gut symbiont Enterobacter sp. AA26 for its use as probiotics in sterile insect technique applications. BMC Biotechnology 19(Suppl. 2):90.

BIMBILE SOMDA, N.S., H. MAÏGA, W. MAMAI, H. YAMADA, J. BOUYER et al. (2019). Insects to feed insects – feeding *Aedes* mosquitoes with flies for laboratory rearing. Scientific Reports 9:11403.

BOND, J.G., A. RAMÍREZ-OSORIO, N. AVILA, D.O. CARVALHO, K. BOURTZIS et al. (2019). Optimization of irradiation dose to *Aedes aegypti* and *Ae. albopictus* in a Sterile Insect Technique program. PLoS ONE 14(2):e0212520.

BOUYER, J. and M.J.B. VREYSEN (2019). Concerns about the feasibility of using "precision guided sterile males" to control insects. Nature Communications 10:3954.

BOUYER, J., N.H. CARTER, C. BATAVIA and M.P. NELSON (2019). The ethics of eliminating harmful species: the case of the tsetse fly. BioScience 69:125-135.

CULBERT, N.J., J.R.L. GILLES and J. BOUYER (2019). Investigating the impact of chilling temperature on male *Aedes aegypti* and *Aedes albopictus* survival. PLoS ONE 14(8):e0221822.

DE MEEÛS, T., S. RAVEL, P. SOLANO and J. BOUYER (2019). Negative density dependent dispersal in tsetse flies: a risk for control campaigns? Trends in Parasitology 35(8):615-621.

DE MEEÛS, T., S. RAVEL, P. SOLANO and J. BOUYER (2019). Response to the Comments of J.S. Lord. Trends in Parasitology 35(10):742.

DEVESCONI, F., C.A. CONTE, E.I. CANCIO MARTINEZ, C. CACERES, K. BOURTZIS et al. (2019). Symbionts do not affect the mating incompatibility between the Brazilian-1 and Peruvian morphotypes of the *Anastrepha fraterculus* cryptic species complex. Scientific Reports 9(1):18319.

DIALLO, S., M.T. SECK, M.J.B. VREYSEN, A.G. PARKER, J. BOUYER et al. (2019). Chilling, irradiation and transport of male *Glossina palpalis gambiensis* pupae: effect on the emergence, flight ability and survival. PLoS ONE 14:e0216802.

DROSOPOULOU, E., A. GARIOU-PAPALEXIOU, E. KARAMANOU, A.A. AUGUSTINOS, K. BOURTZIS et al. (2019). The chromosomes of *Drosophila suzukii* (Diptera: Drosophilidae): detailed photographic polytene chromosome maps and in situ hybridization data. Molecular and General Genetics 294:1535-1546.

GUNATHILAKA, N., T. RANATHUNGE, L. UDAVANGA, A. WIJEGUNAWARDENA, J.R.L. GILLES and W. ABEVEWICKREME (2019). Use of mechanical and behavioural methods to eliminate female *Aedes aegypti* and *Aedes albopictus* for sterile insect technique and incompatible insect technique applications. Parasites Vectors 12:148.

HALLMAN, G.J., G. DEMIRBAS-UZEL, E. CANCIO-MARTINEZ, C.E. CÁCERES-BARRIOS, M.J.B VREYSEN et al. (2019). Comparison of populations of *Ceratitis capitata* (Diptera: Tephritidae) from three continents for susceptibility to sold phytosanitary treatment and implications for generic cold treatments. Journal of Economic Entomology 112:127-133.

HAQ, I.U., A.M.M. ABD-ALLA, U. TOMAS, K. BOURTZIS, C. CACERES et al. (2019). Cryopreservation of the Mediterranean fruit fly (Diptera: Tephritidae) VIENNA 8 genetic sexing strain: no effect on large scale production of high quality sterile males for SIT applications. PLoS ONE 14(1):e0211259.

KOSKINIOTI, P., E. RAS, A.A. AUGUSTINOS, C. CACERES, K. BOURTZIS et al. (2019). The effects of geographic origin and antibiotic treatment on the gut symbiotic communities of *Bactrocera oleae* populations. Entomologia Experimentalis et Applicata 167:197-208.

KYRITSIS, G.A., A.A. AUGUSTINOS, I. LIVADARAS, C. CÁCERES, K. BOURTZIS et al. (2019). Medfly-Wolbachia symbiosis: genotype x genotype interactions determine host's life history traits under mass rearing conditions. BMC Biotechnology 19(Suppl. 2):96.

LOBB, L.N., G. MUNHENGA, H. YAMADA, L.L. KOEKEMOER (2019). The effect of egg storage of laboratory reared *Anopheles arabiensis* (Diptera: Culicidae) on egg hatch synchronisation, pupation success and pupal production time. African Entomology 27(2):360-365.

LUTRAT, C., D. GIESBRECHT, E. MAROIS, S. WHYARD, J. BOUYER et al. (2019). Sex sorting for pest control: it's raining men! Trends in Parasitology 35(8):649-662.

MAIGA, H., W. MAMAI**,** N.S. BIMBILE SOMDA, A. KONCZAL, T. WALLNER et al. (2019). Reducing the cost and assessing the performance of a novel adult mass-rearing cage for the dengue, chikungunya, yellow fever and Zika vector, *Aedes aegypti* (Linnaeus). PLoS Neglected Tropical Diseases 13(9):e0007775.

MAMAI, W., H. MAIGA, N.S. BIMBILE-SOMDA, A. KONCZAL, T. WALLNER et al. (2019). The efficiency of a new automated mosquito larval counter and its impact on larval survival. Scientific Reports 9:7413.

MAMAI, W., N.S. BIMBILE SOMDA, H. MAIGA, A. KONCZAL, T. WALLNE et al. (2019). Black soldier fly (*Hermetia illucens*) larvae powder as a larval diet ingredient for mass-rearing *Aedes* mosquitoes. Parasite 26:57.

MAREC, F. and M.J.B. VREYSEN (2019). Advances and Challenges of Using the Sterile Insect Technique for the Management of Pest Lepidoptera. Insects 10:371.

MECCARIELLO, A., M. SALVEMINI, P. PRIMO, B. HALL, K. BOURTZIS et al. (2019). Maleness- on-the-Y (MoY) orchestrates male sex determination in major agricultural fruit fly pests. Science 365:1457-1460.

MEZA, J.S., C. CACERES and K. BOURTZIS (2019). Slow larvae mutant and its potential to improve the pupal color-based genetic sexing system in Mexican fruit fly (Diptera: Tephritidae). Journal of Economic Entomology 112(4):1604-1610.

MOREIRA, M., A.F. AGUIAR, K. BOURTZIS, A. LATORRE and M. KHADEM (2019). *Wolbachia* (Alphaproteobacteria: Rickettsiales) infections in isolated aphid populations from oceanic islands of the Azores Archipelago: revisiting the supergroups M and N. Environmental Entomology 48(2):326-334.

MUTIKA, G.N., A.G. PARKER, and M.J.B. VREYSEN (2019). Tolerance to a Combination of Low Temperature and Sterilizing Irradiation in Male *Glossina palpalis gambiensis* (Diptera: Glossinidae): Simulated Transport and Release Conditions. Journal of Insect Science 19(5):1.

PEREIRA, R., W. ENKERLIN, C. CÁCERES, D. LU and M.J.B. VREYSEN (2019). Area-wide management of fruit flies using the sterile insect technique. IOBC-WPRS Bulletin 146:75-78.

PLEYDELL, D. and J. BOUYER (2019). Biopesticides improve efficiency of the sterile insect technique for controlling mosquito-driven dengue epidemics Communications Biology 2:201.

RORIZ, A.K.P., H.F. JAPYASSÚ, C. CÁCERES, M. TERESA VERA and I.S. JOACHIM-BRAVO (2019). Pheromone emission patterns and courtship sequences across distinct populations within *Anastrepha fraterculus* (Diptera-Tephritidae) cryptic species complex. Bulletin of Entomological Research 109(3):408-417.

SASSU, F., K. NIKOLOULI, R. PEREIRA, M.J.B. VREYSEN, C. CACERES et al. (2019). Irradiation dose response under hypoxia for the application of the sterile insect technique in *Drosophila suzukii*. PLoS ONE 14(12):e0226582.

SASSÙ, F., K. NIKOLOULI, R. PEREIRA, M.J.B. VREYSEN, C. CÁCERES et al. (2019). Mass-rearing of *Drosophila suzukii* for Sterile Insect Technique application: Evaluation of two oviposition systems. Insects 10:448.

STATHOPOULOU, P., E.D. ASIMAKIS, M. KHAN, C. CACERES, K. BOURTZIS et al. (2019). Irradiation effect on the structure of bacterial communities associated with the oriental fruit fly, *Bactrocera dorsalis* (Hendel). Entomologia Experimentalis et Applicata 167:209-219.

TEETS, N.M., V.S. DIAS, B. PIERCE, M. SCHETELIG, A.M. HANDLER et al. (2019). Overexpression of an antioxidant enzyme improves male mating performance after stress in a lek-mating fruit fly. Proceedings of the Royal Society B: Biological Sciences 286:20190531.

YAMADA, H., C. KRAUPA, A.G. PARKER, H. MAIGA, J. BOUYER et al. (2019). Mosquito mass rearing: who's eating the eggs? Parasite 26:75.

YAMADA, H., H. MAIGA, D. CARVALHO, W. MAMAI, A.G. PARKER et al. (2019). Identification of critical factors that significantly affect the dose-response in mosquitoes irradiated as pupae. Parasites Vectors 12:435.

ZHENG, X.Y., D.J. ZHANG, A.G. PARKER, K. BOURTZIS, J. BOUYER et al. (2019). Incompatible and sterile insect techniques combined eliminate mosquitoes Nature 572:56-61.

Other Publications

2021

FAO/IAEA (2021). E-learning course on Fruit Sampling for Area-Wide Fruit Fly Programmes https://elearning.iaea.org/m2/enrol/index.php?id=1168.

FAO/IAEA (2021). E-learning course on Action Plan Against Quarantine Fruit Fly Species of the Genus Batrocera spp. (in Spanish) https://elearning.iaea.org/m2/course/view.php?id=914.

FAO/IAEA. (2021). Guidelines for Biosafety and Biosecurity in Mosquito Rearing Facilities, Food and Agriculture Organization of the United Nations/International Atomic Energy Agency. Vienna, Austria. 7 pp. https://www.iaea.org/sites/default/files/guidelines_for_mosquito_facilities.pdf.

FAO/IAEA (2021). Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management, 2nd ed., Dyck V.A., Hendrichs J. and Robinson A.S., (Eds.), CRC Press, Boca Raton, FL, USA. 1216pp. https://doi.org/10.1201/9781003035572.

FAO/IAEA (2021). Area-Wide Integrated Pest Management: Development and Field Application, Hendrichs J., Pereira R. and Vreysen M.J.B., (Eds.), CRC Press, Boca Raton, FL, USA. 1028pp. https://doi.org/10.1201/9781003169239.

FAO/IAEA (2021). Animated infographic on Fruit Fly Standards can Help Gain Market Access. https://www.iaea.org/newscenter/multimedia/videos/fruit-fly-standards-can-help-gain-market-access

Insects (2021). Special Issue on Sterile Insect Technique (SIT) and Its Applications. K. Bourtzis and M.J.B. Vreysen (eds.). https://www.mdpi.com/si/28202.

2020

BMC GENETICS (2020). Volume 21 (Suppl. 2) Proceedings of an FAO/IAEA Coordinated Research Project on Comparing Rearing Efficiency and Competitiveness of Sterile Male Strains Produced by Genetic, Transgenic or Symbiont-based Technologies. K, Bouttzis, C. Cáceres and M.F. Schetelig. (eds.). https://bmcgenet.biomedcentral.com/articles/supplements/volume-21-supplement-2.

FAO/IAEA (2020). Guidelines for Irradiation of Mosquito Pupae in Sterile Insect Technique Programmes, Hanano Yamada, Andrew Parker, Hamidou Maiga, Rafael Argiles and Jérémy Bouyer (eds.), Vienna, Austria. 42 pp. http://www-naweb.iaea.org/nafa/ipc/public/2020-Guidelines-for-Irradiation.pdf.

FAO/IAEA (2020). Dose Mapping by Scanning Gafchromic Film to Measure the Absorbed Dose of Insects During Their Sterilization, Parker, A.; Gomez-Simuta, Y.; Yamada, H. (eds.), Food and Agriculture Organization of the United Nations/International Atomic Energy Agency. Vienna, Austria. 17 pp. https://www.iaea.org/sites/default/files/dose-mapping-gafchromic-2020-11-02.pdf

FAO/IAEA (2020). Mapeo de dosis por escaneo de películas Gafchromic® para medir la dosis de radiación absorbida por insectos durante su esterilización, Parker, A.; Goméz-Simuta, Y.; Yamada, H. (eds.), Sección Control de Plagas de Insectos, FAO/OIEA Programa de Técnicas Nucleares en Alimentación y Agricultura. 16 pp. https://www.iaea.org/sites/default/files/20/11/dose-mapping-gafchromic-2020-11-02-spanish.pdf.

IAEA/OIRSA (2020). Guía armonizada de taxonomía e identificación de tefritidos que pudieran ser considerados de importancia económica y cuarentenaria en América Latina y el Caribe. Guillen Aguilar. Vienna, Austria. 209 pp. https://www.iaea.org/sites/default/files/guia210220.pdf.

FAO/IAEA (2020). E-learning Course on Fruit Fly Trapping in Support of Sterile Insect Technique Implementation. https://elearning.iaea.org/m2/enrol/index.php?id=694.

WHO/IAEA (2020). Guidance Framework for Testing the Sterile Insect Technique as a Vector Control Tool Against *Aedes*-borne Diseases. Geneva: World Health Organization and the International Atomic Energy Agency; Licence: CC BY-NC SA 3.0 IGO https://www.iaea.org/sites/default/files/aedes-who-iaea-2020.pdf.

FAO/IAEA (2020). Guidelines for Mark-Release-Recapture procedures of *Aedes* mosquitoes. Jérémy Bouyer, Fabrizio Balestrino, Nicole Culbert, Hanano Yamada, Rafael Argilés (eds.). Vienna, Austria. 22 pp. https://www.iaea.org/sites/default/files/guidelines-for-mrr-aedes_v1.0.pdf.

FAO/IAEA (2020). E-learning course on Packing, Shipping, Holding and Release of Sterile Flies in Area-wide Fruit Fly Control Programmes (Spanish) https://elearning.iaea.org/m2/enrol/index.php?id=745.

FAO/IAEA (2020). Guidelines for Mass-Rearing of Aedes Mosquitoes. Hamidou Maiga, Wadaka Mamai, Hanano Yamada, Rafael Argilés Herrero and Jeremy Bouyer (eds.). Vienna, Austria. 24 pp. http://www-naweb.iaea.org/nafa/ipc/public/Guidelines-for-mass-rearingofAedes-osquitoes_v1.0.pdf.

2019

Australia Scientific Advisory Services/FAO/IAEA (2019). A Guide to the Major Pest Fruit Flies of the World. Piper R., R. Pereira, J. Hendrichs, W. Enkerlin and M. De Meyer (eds.). Scientific Advisory Services Pty Ltd. Queensland, Australia. 43 pp.

BMC BIOTECHNOLOGY (2019). Volume 19 (Suppl 2) Proceedings of an FAO/IAEA Coordinated Research Project on Use of Symbiotic Bacteria to Reduce Mass-rearing Costs and Increase Mating Success in Selected Fruit Pests in Support of SIT Application: biotechnology. C. Cáceres, G. Tsiamis, B. Yuval, E. Jurkevitch and K. Bourtzis. (eds.). https://bmcbiotechnol.biomedcentral.com/articles/supplements/volume-19-supplement-2.

FAO/IAEA (2019). E-training course on Packing, Shipping, Holding and Release of Sterile Flies in Area-wide Fruit Fly Control Programmes. https://elearning.iaea.org/m2/enrol/index.php?id=600.

FAO/IAEA (2019). Fruit Sampling Guidelines for Area-wide Fruit Fly Programmes. Enkerlin W., J. Reyes and G. Ortiz (eds.). Vienna, Austria. 46 pp. http://www.naweb.iaea.org/nafa/ipc/public/ca5716en.pdf.

FAO/IAEA (2019). Guidelines for Blood Collection, Processing and Quality Control for Tsetse Rearing Insectaries. Parker, A., Abdalla, A.M.M., Argilés Herrero, R. (eds.). Vienna, Austria. 60 pp. http://www-naweb.iaea.org/nafa/ipc/public/Guidelines-for-Blood-processing-procedures.pdf.

FAO/IAEA (2019). Spreadsheet for Designing *Aedes* Mosquito Mass-rearing and Release Facilities. Argilés R., Cáceres C. and Bouyer, J. (eds.). Vienna, Austria. 13 pp. http://www-naweb.iaea.org/nafa/ipc/public/Spreadsheet-for-designing-Aedes-facilities.pdf.

FAO/IAEA (2019). Standard Operating Procedures for Detection and Identification of Trypanosome Species in Tsetse Flies. Van Den Abbeele J., Demirbas-Uzel G., Argilés Herrero R., Vermeiren L. and Abd-Alla A. (eds.). Vienna, Austria. 29 pp. http://www-naweb.iaea.org/nafa/ipc/public/SOP-for-Tryp-Id-2020.pdf.

FAO/IAEA (2019). Sterile Insect Release Density Calculations Spreadsheet. Rendón P.A, Enkerlin W.R. and Cáceres C. (eds.). Vienna, Austria. 30 pp. http://www-naweb.iaea.org/nafa/ipc/public/RELEASE-DENSITIES-MANUAL-V.2.0.pdf.

FAO/IAEA (2019). Thematic Plan for the Development and Application of the Sterile Insect Technique (SIT) and Related Genetic and Biological Control Methods for Disease Transmitting Mosquitoes. Vienna, Austria. 93 pp. http://www-naweb.iaea.org/nafa/ipc/public/Thematic-Plan-2019-final.pdf.

FAO/IAEA (2019). Use of Entomopathogenic Fungi for Fruit Fly Control in Area-wide SIT Programmes. Villaseñor A., S. Flores, S. E. Campos, J. Toledo, P. Montoya, P. Liedo and W. Enkerlin (eds.). Vienna, Austria. 44 pp. http://www-naweb.iaea.org/nafa/ipc/public/10072019-eng.pdf.

FAO/IAEA/OIRSA (2019). Plan de Acción en Caso de Detección de Moscas de la Fruta No-Nativas Reguladas del Género *Bactrocera* spp En América Latina y El Caribe. Vienna, Austria, 60 pp. http://www-naweb.iaea.org/nafa/ipc/public/Plan-de-Accion-Bactrocera-spp_agosto2018-Final.pdf.

FAO/IAEA/USDA (2019). Product Quality Control for Sterile Mass-Reared and Released Tephritid Fruit Flies. Version 7.0. IAEA, Vienna, Austria. 164 pp. http://www-naweb.iaea.org/nafa/ipc/public/QCV7.pdf.

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