Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Insect Pest Control Newsletter

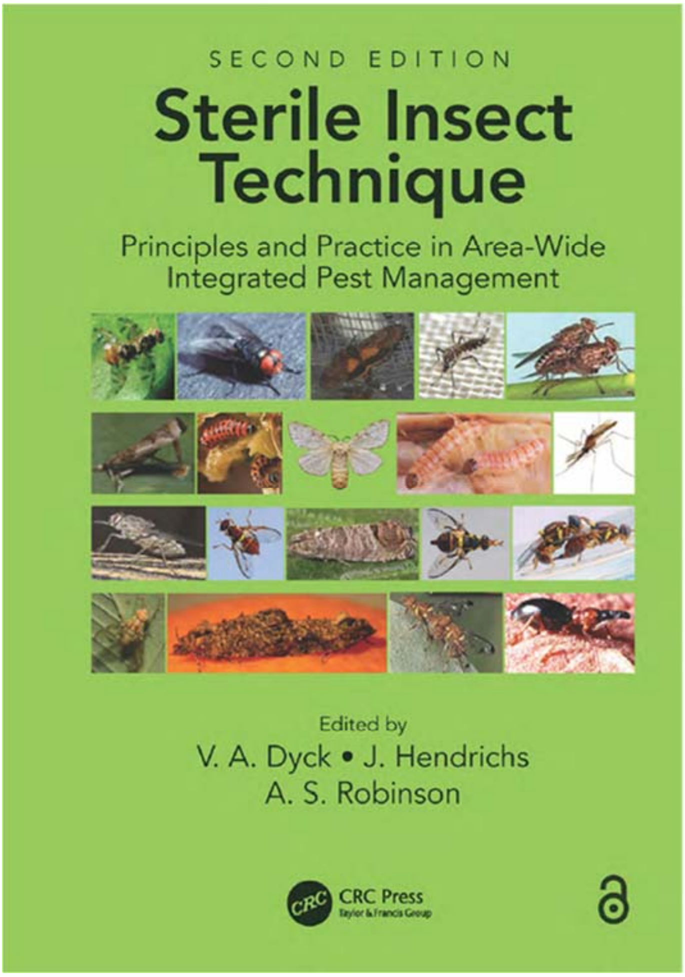
https://www.iaea.org/topics/food-and-agriculture
http://www.fao.org/agriculture/fao-iaea-nuclear-techniques/en/

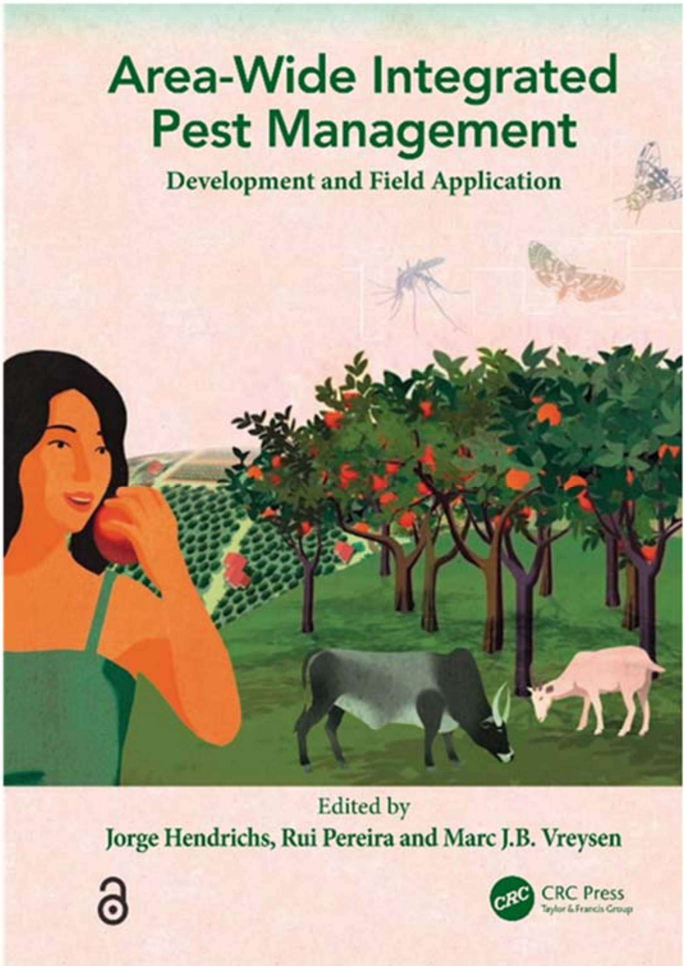
ISSN 1011-274X

No. 97, July 2021

Contents

To Our Readers





Front cover of two books published by the Insect Pest Control Subprogramme in 2021. They are open-source textbooks with over 1000 pages each, and can be accessed and downloaded from the respective links: The second edition of 'Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management' (https://doi.org/10.1201/9781003035572) (left) and 'Area-Wide Integrated Pest Management: Development and Field Application' (https://doi.org/10.1201/9781003169239) (right).

The second edition of the book 'Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management' takes a generic, thematic, comprehensive and global approach in describing the principles and practice of the sterile insect technique (SIT). All aspects of the SIT have been updated and the content considerably expanded. A great variety of subjects is covered, from the history of the SIT to improved prospects for its future application. The major chapters discuss the principles and technical components of applying sterile insects. Other chapters deal with supportive technologies, economic, environmental and management considerations, and the socioeconomic impact of area-wide integrated pest management (AW-IPM) programmes that integrate the SIT. In addition, this second edition includes six new chapters covering the latest developments in the technology, i.e. managing pathogens in insect mass-rearing, using symbionts and modern molecular technologies in support of the SIT, applying post-factory nutritional, hormonal and semiochemical treatments, applying the SIT to eradicate outbreaks of invasive pests and using the SIT against mosquito disease vectors.

The book 'Area-Wide Integrated Pest Management: Development and Field Application' deals with all aspects of the application of AW-IPM approaches that aim at the management of total pest populations, involving a coordinated effort over often larger areas. For major livestock pests, vectors of human diseases and pests of high value crops with low pest tolerance, there are compelling economic reasons for implementing AW-IPM programmes.

I would like to thank the editors, especially Arnold Dyck and Jorge Hendrichs, former Insect Pest Control (IPC) Subprogramme consultant and staff, respectively, for their leading role in these two challenging projects.

With respect to the field programmes, I would like to highlight two important advancements on the implementation of the SIT against fruit flies and human disease vectors (see detailed information further below in this newsletter). The first is the FAO/IAEA support provided to the National Service of Agricultural Health and Food Safety (SENASAG) of Bolivia to build a state-of-the-art fly emergence and release facility to support implementation of the SIT. Three million sterile male Mediterranean fruit flies are being shipped weekly from a mass-rearing and sterilization facility located in Mendoza, Argentina. The sterile flies are released over 2 000 hectares where the pest is present in Cochabamba, Bolivia.

The second advancement refers to an open field pilot trial for a period of three months by the University of Kelaniya, in collaboration with the National Dengue Control Unit, Ministry of Health, Sri Lanka, to evaluate the feasibility of using the SIT to suppress populations of *Aedes albopictus*. Weekly releases of 100 000 sterile male mosquitoes in a 30-ha pilot site started in late March 2021.

Peach harvest in Cochabamba, highlands of Bolivia. (Source: SENASAG).

Collaboration is also an essential part of our mandate, and recently the Sun Yat-sen University (SYSU), Guangzhou, China, was designated as an IAEA Collaborating Centre on 'Developing the Sterile Insect Technique (SIT) for Control of Mosquitoes' for the period 2021–2024. The mandate of the SYSU includes research and implementation of the SIT to manage human disease vectors and to contribute to development of the SIT to facilitate the sustainable and environment-friendly control of *Ae. albopictus*, a major vector of human diseases.

Another achievement is the leading role of IPC staff as guest editors in the publication of a Special Issue on 'Sterile insect technique (SIT) and its applications' in the journal '*Insects*'. The supplement can be found at https://www.mdpi.com/journal/insects/special_issues/mr_sit and includes 26 papers (19 original research articles and 7 reviews with 1 manuscript still under review), covering a wide array of components of the SIT package and focusing on several main groups of SIT target species: plant and livestock pests, and human disease vectors.

Finally, I would like to express concerns about the impact of the COVID-19 pandemic on three main areas of our work. The current situation has reduced our capacity to conduct demand-driven research at the Insect Pest Control Laboratory (IPCL), despite major progress achieved in many research areas. In addition, the implementation of operational field projects was more severely affected due to constraints faced by Member States, but also due to restrictions with respect to providing technical advice and support by staff and experts in the field, as well as the capacity development in other projects and laboratories. Additionally, progress in coordination research projects (CRPs) was also below expectations due to limitations many research institutes faced to conduct their research activities, as well as implementation of Research Coordination Meetings and Consultants Meetings virtually, which defeats the purpose of establishing and maintaining research networks.

Rui Cardoso Pereira
Head, Insect Pest Control Section

Staff

Joint FAO/IAEA Centre of Nuclear Applications in Food and Agriculture

Name	Title	Email	Extension	Location
Qu LIANG	Director	Q.Liang@iaea.org	21610	Vienna

Insect Pest Control Subprogramme

Insect Pest Control Section, Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture
P.O. Box 100, 1400 Vienna, Austria
Tel.: (+) 43 1 2600 26077; Fax: (+) 43 1 26007

Insect Pest Control Laboratory, FAO/IAEA Agriculture & Biotechnology Laboratories
2444 Seibersdorf, Austria
Tel.: (+) 43 1 2600 28404; Fax: (+) 43 1 26007 2874

Name	Title	Email	Extension	Location
Rui CARDOSO PEREIRA	Section Head	R.Cardoso-Pereira@iaea.org	26077	Vienna
Walther ENKERLIN	Entomologist (Plant Pests)	W.R.Enkerlin@iaea.org	26062	Vienna
Maylen GÓMEZ	Entomologist (Livestock and Human Health Pests)	M.Gomez-Pacheco@iaea.org	21629	Vienna
Daguang LU	Entomologist (Plant Pests)	D.Lu@iaea.org	25746	Vienna
Svetlana PIEDRA CORDERO	Programme Assistant	S.Piedra-Cordero@iaea.org	21633	Vienna
Elena ZDRAVEVSKA	Team Assistant	E.Zdravevska@iaea.org	21632	Vienna
Marc VREYSEN	Laboratory Head	M.Vreysen@iaea.org	28404	Seibersdorf
Adly ABD ALLA	Virologist	A.Abdalla@iaea.org	28425	Seibersdorf
Kostas BOURTZIS	Molecular Biologist	K.Bourtzis@iaea.org	28423	Seibersdorf
Jeremy BOUYER	Medical Entomologist (Human Disease Vectors)	J.Bouyer@iaea.org	28407	Seibersdorf
Carlos CÁCERES	Entomologist (Plant Pests)	C.E.Caceres-Barrios@iaea.org	28413	Seibersdorf
Danilo CARVALHO	Molecular Biologist	D.Carvalho@iaea.org	28438	Seibersdorf
Chantel DE BEER	Research Entomologist (Livestock Pests)	C.De-Beer@iaea.org	27321	Seibersdorf
Vanessa DIAS	Entomologist (Post-harvest)	V.Dias-De-Castro@iaea.org	28450	Seibersdorf
Robin GUILHOT	Associate Research Officer	R.Guilhot@iaea.org	27420	Seibersdorf
Wadaka MAMAI	Medical Entomologist (Rearing Specialist)	W.Mamai@iaea.org	28429	Seibersdorf
Hamidou MAIGA	Medical Entomologist	H.Maiga@iaea.org	28421	Seibersdorf
Katerina NIKOLOULI	Genetics (Medical Entomologist)	K.Nikolouli@iaea.org	28756	Seibersdorf
Hanano YAMADA	Entomologist (Human Disease Vectors)	H.Yamada@iaea.org	28429	Seibersdorf
Stephanie BECKHAM	Programme Assistant	S.Beckham@iaea.org	28259	Seibersdorf

Forthcoming Events (2021–2022)

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

Second RCM on Improvement of Colony Management in Insect Mass-rearing for SIT Applications. 30 August–3 September 2021, Vienna, Austria.

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

First RCM on Improving SIT Fruit Fly Field Programmes. 1–5 November 2021, Vienna, Austria.

Second RCM on Mosquito Irradiation, Sterilization and Quality Control. 11–15 July 2022, Vienna, Austria.

First RCM on Rearing of Lepidoptera for SIT Application. 1–5 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 Rearing of Lepidoptera for SIT Application. 8–12 November 2021, Vienna, Austria.

FAO/IAEA Consultancy Meeting on Guideline on Transboundary Shipments of Sterile Insects. 4–8 April 2022, Vienna, Austria.

FAO/IAEA Consultancy Meeting on Mosquito Male Performance. 9–13 May 2022, Vienna, Austria.

III. Other Meetings/Events

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 Training Course on Field Application of SIT and other Control Methods against Aedes mosquitoes in Europe. (under Regional TC Project RER5026). 13–23 September 2021, Valencia, Spain.

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). September 2021, (virtual).

FAO/IAEA Final Coordination Meeting on Enhancing Capacity for Detection, Surveillance and Suppression of Exotic and Established Fruit Fly Species through Integration of Sterile Insect Technique with other Sup-pression Methods (under Regional TC Project RAF5074). Date and venue to be announced.

FAO/IAEA Workshop on Irradiation and Dosimetry. 8–9 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 (2020–2021)

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

Fourth RCM on Mosquito Handling, Transport, Release and Male Trapping Methods. 14–18 September 2020 (virtual).

Fourth RCM on Improved Field Performance of Sterile Male Lepidoptera to Ensure Success in SIT Pro-grammes. 18 May–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).

II. Consultants and Expert Meetings

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

III. Other Meetings/Events

FAO/IAEA/WHO Regional Coordination Meeting on the Potential of SIT for the Integrated Control of *Aedes* Invasive Mosquitoes in Europe (under Regional TC Project RER5022). 24–28 February 2020, Athens, Greece.

FAO/IAEA First Regional Coordination Meeting on Assessing the Efficiency of the Sterile Insect Technique for the Control of the Cocoa Pod Borer (under Regional TC Project RAS5086). 9–13 March 2020, Makassar, Indonesia.

FAO/IAEA First 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). The meeting was conducted virtually and split in four sessions on 14, 17 and 24 April and 1 May 2020.

FAO/IAEA Third Coordination Meeting on Strengthening Regional Capacity in Latin America and the Caribbean for Integrated Vector Management Approaches to Control Aedes Mosquitoes as Vectors of Human Pathogens, particularly Zika Virus (under Regional TC Project RLA5074). 13–16 July 2020 (virtual).

FAO/IAEA meeting to finalize the strategic plan titled ‘Proposal of a Strategic Plan for the Eradication of the Myasis Caused by the New World Screwworm (Cochliomyia hominivorax, Coquerel) in South America and the Subregion Conformed by Uruguay and Border Areas with Argentina, Brazil and Paraguay’ (under Regional TC Project RLA5075). 24–28 August 2020 (virtual).

Fourth Meeting of the Tephritid Workers of Europe, Africa and the Middle East (TEAM). 4–8 October 2020, La Grande-Motte, Montpellier, France (partially virtual).

FAO/IAEA Regional Training Course on Stakeholder Engagement and Communication Strategy Development for SIT Pilot Projects (under Regional TC Project RLA5074). 19–23 October 2020 (virtual).

Americas Congress on Fruit Flies and the 10th Meeting of the Tephritid Workers of the Western Hemisphere (TWWH). 3–7 November 2020 (virtual).

FAO/IAEA Regional Workshop on Data Analysis and Reporting Methodologies (under Regional TC Project RLA5074). 23–27 November 2020 (virtual).

FAO/IAEA Training Course on Packing, Holding and Release of Sterile Fruit Flies and on Area-wide Fruit Fly Trapping (under National TC Project BOL5022). 7–11 December 2020 (virtual).

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 Programs (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).

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).

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	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)	Hamidou Maiga
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

		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	Walther Enkerlin

		Interregional Project	
Interregional	INT5155	Sharing Knowledge on the Sterile Insect and Related Techniques for the Integrated Area-wide Management of Insect Pests and Human Disease Vectors	Rui Cardoso Pereira

Highlights of Technical Cooperation Projects

Reducing Fruit Fly Populations in Different Regions Introducing an Integrated Pest Management Approach Including the Use of the Sterile Insect Technique (BOL5022)

Fruit Fly SIT Pilot Project was Officially Launched in Cochabamba, Bolivia

On 24 March 2021, the National Service of Agricultural Health and Food Safety (SENASAG) of Bolivia launched the country's first sterile insect technique (SIT) fruit fly pilot project in Cochabamba. This project aims to support Bolivia on incorporating the SIT in an area-wide integrated pest management approach to reduce infestations of the Mediterranean fruit fly, *Ceratitis capitata*, in selected fruit production areas located in the Bolivia highlands.

Sterile fly release farmers ceremony over commercial peach orchards affected by fruit flies.

At the opening ceremony, Mr Fredy Colque, the national project counterpart stated that "Fruit flies are inflicting serious damage to fruit production in Bolivia. Through the use of the sterile insect technique, fruit fly populations will be suppressed resulting in the opening of export markets for fruits produced in Bolivia as has happened in other countries using the SIT, such as Argentina and Chile".

The fruit flies lay eggs under the skin of fruits and vegetables, which develop into larvae that destroy harvests. The SIT works by mass-rearing fruit fly insects and then using radiation to sterilize the males. This project will validate SIT at a pilot scale to help Bolivia control this pest that cause economic damage to fruit crops such as apples, peaches and apricots.

Bolivia has developed a national programme that has built a state-of-the-art fly emergence and release facility to support the SIT implementation. Despite major challenges caused by the global COVID-19 pandemic, with the support from the IAEA and FAO, 3 million sterile male flies are being shipped weekly from a mass-rearing and sterilization facility located in Mendoza, Argentina. The sterile flies are released over 2 000 hectares where the pest is present in Cochabamba. Future capacity building activities aimed at expanding the areas under SIT in Bolivia, such as additional training of human resources and preparation of standard operation procedures for each of the SIT stages are being included in the national project currently under design for the next IAEA-TC cycle, aiming at continuing the support for SIT implementation in Bolivia.

Strengthening Food Security through Efficient Pest Management Schemes Implementing the Sterile Insect Technique as a Control Method (RLA5082)

Second Coordination Meeting of RLA5082, 7 April 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 work plan. Participating Member States included Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, and Venezuela.

Virtual Coordination Meeting of Technical Cooperation Project RLA5082 (Mr Carlos Soto top right former project Designated Team Member).

Despite the COVID-19 pandemic that affected project implementation in 2020, a number of activities were implemented some through virtual means and others through home-based-assignment (HBA) contracts. These included: 1) A high level training course on artificial mass-rearing of insects offered by the North Carolina State University, 2) E-learning course on Trapping for Area-Wide Fruit Fly Programmes, 3) Spanish version of the e-learning course on Transport, Packing and Release of Sterile Flies, and 4) Publication of the manual entitled 'Harmonized identification guideline of tephritids that might be considered of economic and quarantine importance in Latin America and the Caribbean' (in Spanish). Given the limitations to implement face-to-face meetings and activities, emphasis was given to the procurement of materials and equipment. Substantial amount of financial resources was invested in traps, lures, microscopes, GPS devices and other items in support of the regional trapping network.

Regarding the 2021 work plan, it was decided that some of the activities such as training events and manuals for harmonization of guidelines and procedures will be implemented by virtual means and through HBAs. Face-to-face activities were rescheduled for the third and fourth quarters of 2021 and some to be implemented in 2022.

Project countreparts agreed in nominating Ms Wilda Ramirez, the Director for Plant Protection from National Service of Agri-Food Health and Quality (SENASA) of Argentina to replace Mr Carlos Soto, fomer Director of the Moscamed Programme on behalf of Ministry of Agriculture, Livestock and Food (MAGA) Guatemala, as a new Designated Team Member (DTM). The project team acknowlededed the valuable contributions of Mr Soto to the regional project and welcomed Ms Ramirez as the new DTM.

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

First Regional Coordination Meeting, 22–24 February 2021 (virtual)

The meeting was attended by 22 participants including the counterparts from 13 Member States of Latin America and Caribbean Region: Antigua and Barbuda, Argentina, Bahamas, Bolivia, Brazil, Chile, Cuba, Ecuador, Jamaica, Nicaragua, Panama, Peru, and Uruguay. Given the travel restrictions posed by the COVID-19 pandemic, the meeting was held virtually. The counterparts fulfilled the objectives of the meeting by presenting the progress made and the challenges they faced at national and regional levels on integrating the sterile insect technique (SIT) with other control methods to supress *Aedes* mosquitoes, which are the vectors of major arboviruses, such as dengue and Zika.

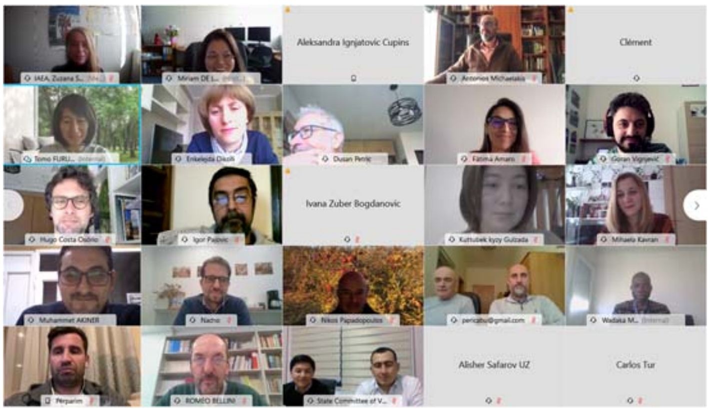
New facility for mosquito mass-rearing is under the construction in Instituto Nacional de Investigacion en Salud Publica 'Dr Leopoldo Izquieta Perez' (INSPI), Quito, Ecuador.

During the meeting, technical discussions focused on the 'Phased Conditional Approach' to SIT application and field validation, since this is a fundamental tool for the initial preparation and implementation of the pilot trial. Two participating Member States, Brazil and Cuba, have already started the small-scale releases of sterile male mosquitoes in their pilot sites, with promising results. These field trials were mainly supported by their respective national TC projects. Ecuador has also been making good progress on getting prepared for its first pilot sterile male releases at the end of 2021. In addition, the outputs, activities, and milestones of this regional project were discussed, defined, and agreed for 2021 by all participating Member States in order to harmonize the methodologies, and establish a solid and supportive network at the regional level.
Also, two regional training courses will be organised virtually in 2021, on methods for mass-rearing and irradiation of *Aedes* mosquitoes and mosquito monitoring, data collection and data management.

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

First Coordination Meeting, 16–18 February 2021 (virtual)

Since the late 1990s, disease transmitting *Aedes* species have been introduced into Europe, they are now spreading rapidly and becoming a widespread significant public health risk which needs to be effectively addressed. As part of an area-wide integrated pest management (AW-IPM) approach to manage insect pest populations, the Joint FAO/IAEA Programme, has been supporting the integration of the sterile insect technique (SIT) into existing national pest control strategies, to help delay, curtail and contain the spread of pathogen-carrying mosquitoes in Europe. To continue building on the experience gained under RER5022 'Establishing Genetic Control Programmes for *Aedes* Invasive Mosquitoes' (2016–2019), a new regional TC project (RER5026) was approved for the years 2021–2023 to support Member States with the development of the required capacities to effectively implement SIT within their integrated mosquito control strategies. The first coordination meeting was held virtually on 16–18 February 2021 with 20 participants from 11 countries (Albania, Bosnia and Herzegovina, Croatia, Cyprus, Greece, Kyrgyzstan, Montenegro, Portugal, Serbia, Turkey and Uzbekistan) as well as five experts from Italy, France and Spain. Participating Member States and experts presented recent work and achievements of their institutions related with the SIT application against *Aedes* mosquitoes.



Participants of the first coordination meeting of RER5026 (virtual).

Together, the meeting reviewed and analysed the progress, discussed issues and challenges, and agreed on the project workplan and activities. Among activities, those identified to be carried out in 2021 include i) Mark-Release-Recapture data collection and analysis ii) Quality assessment of SIT and conventional control measures under field conditions iii) A vector control need assessment and iv) A training course on Field Application of SIT and other Control Methods against *Aedes* mosquitoes in Europe'. Finally, the experts evaluated the responses to a questionnaire submitted by the RER5026 counterparts to define their actions within the phased conditional approach proposed by IAEA and advised on individual action plans of counterparts.

Managing and Controlling *Aedes* Vector Populations Using the Sterile Insect Technique (RAS 5082)

Ongoing releases of sterile males for integrated management of dengue in Sri Lanka

To boost Sri Lanka's defence against vector-borne diseases, the Joint FAO/IAEA Programme have assisted local authorities through a four-year technical cooperation project (SRL5047) from 2016–2019 to help establish a National Centre for Research, Training and Services in Medical and Molecular Entomology, as a first step towards more effective control of vector-borne diseases.

Building on this capacity, continuously under the support of regional TC project RAS5082, the University of Kelaniya, in collaboration with the National Dengue Control Unit, Ministry of Health, recently initiated a pilot field trial for the release of sterilized male *Aedes albopictus* mosquitoes in Sri Lanka. Initial field release was held in Kidagammula Grama Niladhari area in the District of Gampaha on 29 March 2021.

Map of the release and the control sites in Kidagammula Grama Niladhari area in the District of Gampaha, Sri Lanka.

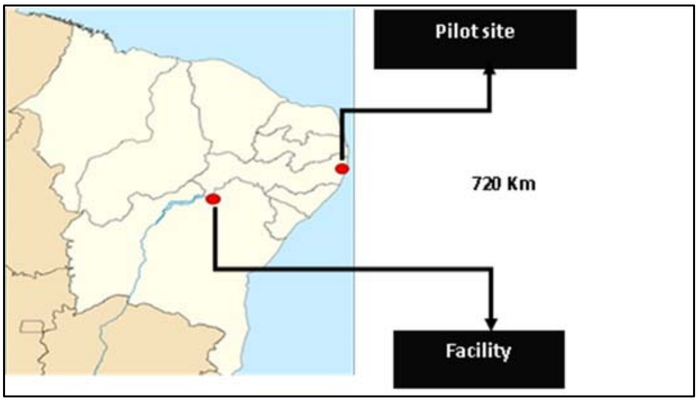
The area was selected based on the geographical setting, human population density and its close to an urban center. Density of the selected *Ae. albopictus* population was high during the last five years in the selected area. Weekly releases of 100 000 sterile male mosquitoes in a 30 ha pilot site is ongoing. Entomological and epidemiological monitoring are also ongoing for six months and based on the results of the initial trial, an operational programme will be strategically planned in the future.

The release of sterile male Aedes albopictus *during the initial field release in Kidagammula Grama Niladhari area in the District of Gampaha, Sri Lanka.*

Both institutions are looking forward to a successful outcome of this new technique for public health, which can be used to control dengue vector mosquitoes in Sri Lanka in the near future. Release of sterile mosquitoes was a landmark event in the dengue prevention campaign in Sri Lanka.

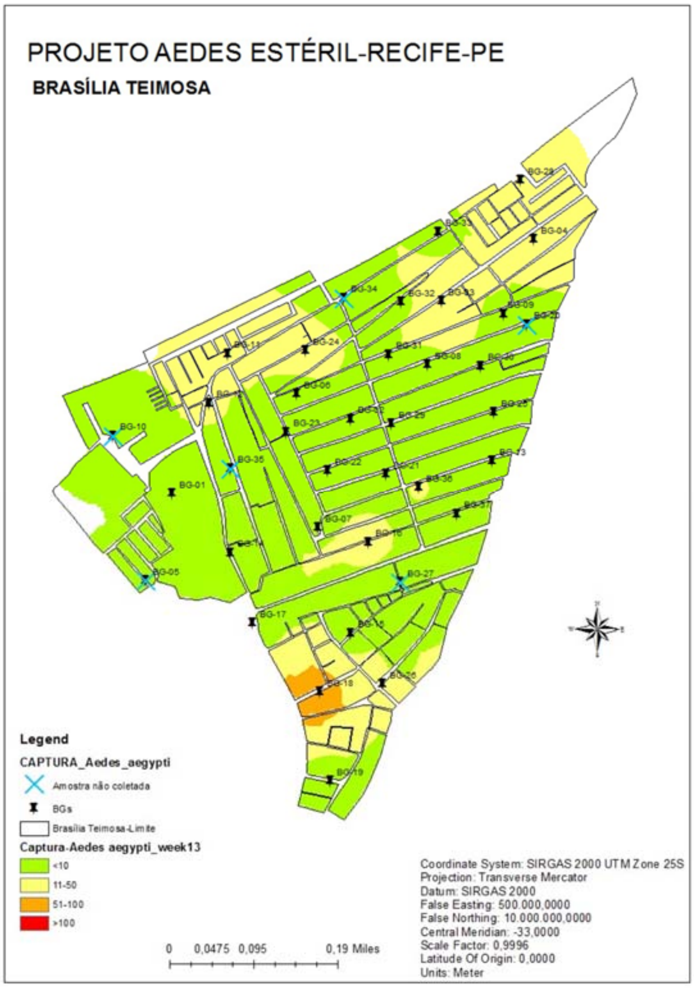
Using the Sterile Insect Technique to Evaluate a Local Strain in the Control of *Aedes aegypti* (BRA5061)

In October 2020, Moscamed Brazil initiated a pilot project in Brasilia Teimosa neighbourhood, located in Recife, Pernambuco, to demonstrate the feasibility of using the SIT to suppress *Aedes aegypti*, the main vector of several arboviral diseases including chikungunya, dengue, and Zika. The pilot site is a typical urban community with a surface area of 60 ha and surrounded by water on two sides and 720 km away from the rearing facility (see figure below).



Location of the suppression pilot in Brasilia Teimosa, Recife, Pernambuco and production of mosquitoes in Juazeiro, Bahia, Brazil.

Weekly releases of 250 000 to 350 000 sterile males are being carried out, along with successful public dissemination and awareness campaigns under the support of the Municipality of Recife through the Emergency Center for the Sterile Mosquito of Recife (CEMER) of the Health Secretary. Mass-rearing, chilling, and compaction procedures of *Ae. aegypti* (Recife strain) are routinely carried out by the already qualified technical team of the Production Unit of Sterile *Aedes* (UPAE) at the Biofábrica Moscamed, located in Juazeiro – Bahia State. Forty-eight hours after emergence, male *Ae. aegypti* mosquitoes are transported to Recife, Pernambuco by plane in thermal boxes at the controlled temperature of 8°C. The flight takes on average one hour and upon arrival, the mosquitoes are taken to the Nuclear Energy Department of the Federal University of Pernambuco (UFPE) to be irradiated in a Gammacell-220 with 65 Gy resulting in almost 100% sterility. Irradiated males are marked with fluorescent powder prior to the field releases (at 3 to 4 days of age). Despite the difficulties due to the ongoing COVID-19 pandemic, the evidence of suppression of *Ae. aegypti* in Brasília Teimosa is promising. Recent data shows that there was a 30% reduction in egg hatch and a 19% reduction in the wild mosquito population since the initiation of releases of sterile *Ae. aegypti* males as compared with the untreated control area. To ensure more effective and efficient results, there is a plan to release the sterile male *Ae. aegypti* mosquitoes twice a week.



The map of the area selected for the pilot project using SIT against Aedes aegypti *in Brasilia Teimosa, Recife city, Pernambuco, Brazil, illustrating the wild mosquito density distribution on week 13 (2021).*

Coordinated Research Projects (CRPs)

Project Number	Ongoing CRPs	Project Officer
D4.10.26	Improved Field Performance of Sterile Male Lepidoptera to Ensure Success in SIT Programmes (2016–2021)	Marc Vreysen
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)	Hanano Yamada

The Final RCM on *Improved Field Performance of Sterile Male Lepidoptera to Ensure Success in SIT Programmes*, 18–21 May 2021 (virtual)

The RCM was attended by 30 research contract and agreement holders, as well as observers from Argentina, Bangladesh, Canada, Chile, India, Israel, Mauritius, New Zealand, South Africa, Syrian Arab Republic, and the United States of America despite the difficulties caused by the time differences.

The European grapevine moth, Lobesia botrana, *the study object of several CRP participants.*

Twenty-one presentations on the progress with their research were delivered, and the quality was of high standards. The various topics in the presentations covered all expected outputs of the CRP, such as improved rearing and maintenance of insect colonies, better collection and irradiation methods, the application of two-sex or male-only release strategies, improved handling, transport and release methods, practical and effective methods for quality assessment, and improved deployment strategies on cost-effectiveness and outcomes.

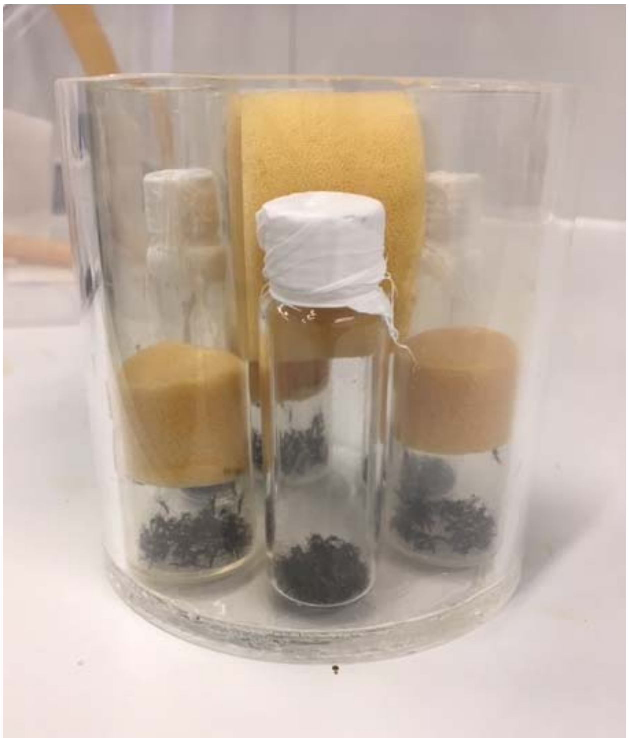
The following are some of the main achievements of this CRP:

- New larval diets developed for sugarcane borers and the European grapevine moth and the impact on moth quality and performance assessed.
- Use of radiation and pupal weight as potential sex separation methods of sugarcane borers.
- Effects of artificial diet components assessed on life history traits and flight ability of *Grapholita molesta*.
- Long distance transport (Canada to New Zealand) of sterile male codling moths resulted in high quality releases with good suppression in the trial areas.
- Various cold treatment of the false codling moth and the effects on field performance assessed during summer and winter releases.
- Effects of male-only and bi-sexual releases on induced sterility assessed in laboratory cages.
- Influence of scales dislodgement and radiation hormesis assessed on competitiveness of *Spodoptera litura*.

The results of the CRP will be published in a special issue of the peer reviewed journal 'Insects'.

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

The RCM was held virtually and was attended by scientists of 19 participating research institutes from Bangladesh, Brazil, Burkina Faso, Canada, China, Ecuador, France, Greece, Indonesia, Italy, Mauritius, Mexico, Philippines, Senegal, South Africa, Spain, Thailand and United States of America. The presentations by the participants covered various topics under the headings Irradiation & Sterilization, and Quality control. Research activities related to irradiator qualification, dosimetry, factors affecting dose-response, effects of irradiation on vector competence and symbionts, as well the development of tools for process and product quality control were presented and discussed. Most participants were present during all sessions, despite the large time difference between continents. The virtual meeting format allowed the participation of several observers, which was beneficial for the institution's research groups.



Irradiation of mosquito adults in air, or in anoxia.

Developments at the Insect Pest Control Laboratory (IPCL)

Genetics and Molecular Biology

The white pupae mutation: from its detection to gene discovery

One of the determining factors that made the application of the sterile insect technique (SIT) in Mediterranean fruit fly *Ceratitis capitata* a success story was the development of genetic sexing strains (GSS). In the mid-1970's a morphological mutation that was changing the colour of the Mediterranean fruit fly puparium was identified. The mutation fails to tan the puparium thus resulting in white pupae (wp) phenotype instead of the wild-type brown colour. The cascade of research activities that followed the identification of this mutation aimed to dissect the biochemical, genetic and biological aspects that were ruling this mutation and conclude whether it could be used as a selectable marker for the construction of GSS in support of SIT applications for the population control of this major agricultural pest.

In the late 1970's, classical genetic studies indicated that the wp phenotype is due to a recessive mutation in a single autosomal gene. These findings set the ground for the linkage of the pupal colour gene with the sex determining chromosome that would allow for sex separation at the pupal stage. Indeed, at the beginning of the 1980's, a Y-autosome translocation with the recessive *wp* locus was developed, while cytogenetic studies of this Y-autosome translocation running in parallel placed the autosomal *wp* locus on the right arm of chromosome 5 of the Mediterranean fruit fly genome. That translocation was used to develop what is nowadays known as the first generation GSS of *C. capitata* in which pupal colour dimorphism between males and females was used for sex separation. Further studies focusing on polytene chromosome analysis demonstrated that the *wp* locus is linked to a *temperature-sensitive lethal (tsl)* gene, which is the second selectable marker of the VIENNA 7 and VIENNA 8 GSS currently used in all Mediterranean fruit fly SIT operational programmes worldwide.

It soon became evident that the genetic stability of a GSS under large-scale mass-rearing conditions was of paramount importance. Recombination events taking place between the *white pupae* locus and the translocation breakpoint can lead to accumulation of recombinants and subsequent breakdown of the strain. This challenge was sorted out by the establishment of a filtering system as well as by inducing a chromosomal inversion called D53 which was integrated into the VIENNA 8 GSS (VIENNA 8 D53+). Advanced cytogenetic studies indicated that the *wp* locus is located inside the D53 inversion, close to its right breakpoint.

Apart from *C. capitata*, the white pupae phenotype has been independently identified in *Bactrocera dorsalis* and *Zeugodacus cucurbitae*, two tephritid species of major agricultural importance (Figure below). Despite the semi-centennial history of the *wp* mutation as a selectable marker, till recently it was unknown to the scientific community which is the gene and the causal mutation that results in these white pupae strains. A recent study by Ward et al. (2021) https://doi.org/10.1038/s41467-020-20680-5 employed classical and modern genetic approaches, including genetics, cytogenetics, genomics, transcriptomics, bioinformatics, and gene editing to identify and functionally characterize the *wp* genetic locus in *C. capitata*, *B. dorsalis*, and *Z. cucurbitae*. In all three tephritids, a single candidate gene was identified which was linked with a metabolite transport protein that contains a Major Facilitator-like superfamily domain, and the wp phenotype is produced by parallel mutations in a single, conserved gene. The candidate *wp* gene has been functionally characterized via CRISPR/Cas9-mediated knockouts and confirmed that this gene is responsible for the wp phenotype.

White colour pupae of tephritid species Zeugodacus cucurbitae, Ceratitis capitata and Bactrocera dorsalis *(left to right) (Photo credit: Georgia Gouvi – FAO/IAEA).*

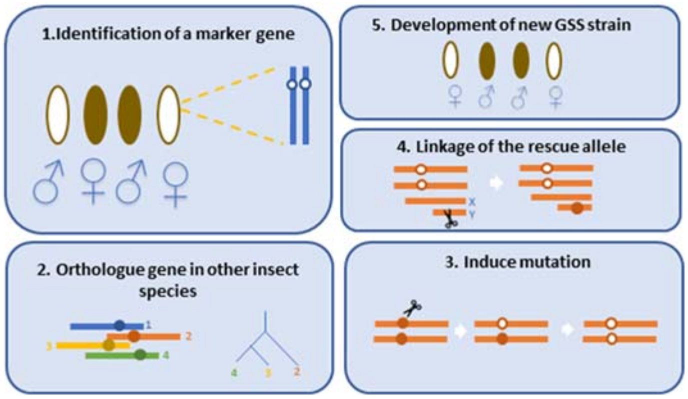
Since the development of the SIT, Member States have continuously benefited from the application of the SIT to manage populations of fruit fly pests. In the case of the Mediterranean fruit fly, the operational programmes have been remarkably advanced due to the development of GSS. The vast amount of research performed since the identification of the wp phenotype has shed light to what previously was thought to be a black box. Currently the gene responsible for the wp phenotype and its genetic traits, its relative position on the chromosome and the distance from other marker genes, the characterization of the inversion and the nature of the independent mutations in tephritids have empowered a number of scientists towards their efforts to develop GSSs in other significant insect pest species of agricultural, veterinary and human health importance.

New approaches for the development of genetic sexing strains

The efficacy and the cost-effectiveness of the SIT is greatly enhanced by the release of male-only sterile insects. The sterile males will mate with the wild females leading to the reduction of the target population. If sterile female insects are released, then the efficacy of the technique will be reduced as the sterile males and females may mate together. Also, the sterile female can still cause damage by stinging the fruits in the case of fruit flies. Successful male-only releases have been possible due to the development of GSSs. It has been well demonstrated that GSSs not only increase the efficiency of the technique in fruit flies but also reduce the overall costs regarding the rearing, emergence and release, and the monitoring of the insect population.

The development of a GSS depends on two components: (a) a selectable marker that includes morphological (e.g. different sizes of pupae), phenotypical (e.g. colour of the pupae) or conditional (e.g. lethality at elevated temperatures) changes and (b) the pseudo-linkage of the wild type (rescue) allele of this selectable marker with the male determining region. Traditionally this linkage and the development of GSSs are achieved through irradiation that can induce chromosomal translocations. Then, a genetic screening is being demonstrated to detect male-linked inheritance of the rearrangement. Not all translocations are equally appropriate for use in a GSS, e.g., translocations involving multiple autosomes have a high fitness cost. After applying an appropriated scheme of crosses and backcrosses, individuals with the dominant wild-type allele pseudo-linked to the Y-chromosome are identified and used for the development of a strain that produces males as the wild-type phenotype and mutant females.

In the frame of the CRP on 'Generic approach for the development of genetic sexing strains for SIT applications' a new concept for the development of GSSs is being introduced (Figure below). Firstly, genes that could be used as selectable markers will be characterized. An example of this marker is the *wp* gene in *C. capitata*. Even though this marker is used in the GSSs for *C. capitata*, *B. dorsalis* and *Z. cucurbitae*, the gene that is responsible for this phenotypic trait was only very recently identified and characterized (see previous section). Once the molecular basis of a gene mutation is known, the orthologue gene can be identified and mutations can be induced through modern molecular-based techniques using molecular 'scissors', in any species of interest. Moreover, a rescue allele (wild type) can be transferred in a well-characterized chromosome region located only in male insects. In Tephritidae species, this could be any region that is transcriptionally active on the Y chromosome and does not encode a vital gene for the insect.



An overall presentation of the experimental procedure of the generic approach for the development of genetic sexing strain (GSS) using new molecular tools. It consists of five steps that include: (a) the identification of the gene that is responsible for a certain phenotype (selectable marker), (b) the identification of orthologue genes in other insect species, (c) the induction of mutation through modern molecular tools, (d) linkage of the rescue allele (wild type) to the male determining region (in the case of Tephritidae, this resides on the Y-chromosome) and (e) the development of a new GSS strain.

Through this procedure new GSSs can be developed in a faster and more sufficient way. In contrast to the traditional way, a controllable, straightforward process will be available with two significant advantages. The possibility of the insect strain breakdown will be drastically reduced as no random translocation are involved in the procedure; therefore, the recombination rate will be limited. Moreover, having semi-sterile GSS will be avoided since no translocations will be required for the pseudo-linkage of the wild type (rescue) allele to the male determining region. The rescue allele will be introduced in the Y-chromosome without interrupting any genomic regions from autosomal chromosomes. In this way, the sperm produced by males of the GSS will be 100% genetically balanced and the GSSs strains will be fertile.

Following the discovery of the *wp* gene in *C. capitata*, *B. dorsalis* and *Z. cucurbitae*, we have been actively engaged in research efforts to discover the genes responsible for key phenotypic traits which have already been used or could potentially be used as selectable markers for the development of GSSs in SIT target species. These markers include: (a) the *temperature sensitive lethal (tsl)* gene, which has been used, in addition to the *wp* gene, as a selectable marker in the VIENNA 7 and VIENNA 8 GSSs of *C. capitata*; (b) the *black pupae (bp)* gene, which is the only selectable marker in the respective GSS of *Anastrepha ludens* and *Anastrepha fraterculus* and (c) the *red-eye (re)* gene, which has been used, in addition to the pupal size dimorphism, in the respective GSS of *Aedes aegypti*.

The discovery of the genes responsible for the above mentioned phenotypic traits (white pupae, black pupae, red eye and temperature sensitive lethal), and the introduction of their wild type (rescue) alleles, close to the male determining regions, will set the ground for the faster development of GSS, which will be more genetically stable and of better quality.

Plant Pests

Development of the SIT package for *Drosophila suzukii*

Mr Robin Guilhot from France was appointed in October 2020 at the IPCL as a Junior Professional Officer with the support of the Government of France. During his appointment, Robin will focus on improving the mass-rearing protocols for the spotted wing Drosophila (SWD), *Drosophila suzukii,* for SIT application.

The SWD is an invasive insect pest that attacks a wide range of soft fruits and causes major economic losses both in open field and confined production systems. The SIT is considered as having potential to manage SWD populations in confined environments such as greenhouses. Since 2016, the IPCL Plant Pests group has been developing the SIT package for SWD and progress has been reported with respect to radiation doses response curves, selection of an appropriate male sterilization dose and mass-rearing components such as adult holding cages, eggs and pupae collection systems as well as development of suitable adult and larval diets.

Robin's main research topics on SWD at the IPCL are focused on developing quality control protocols for SWD, such as developing a protocol to assess the sexual compatibility and competitiveness of SWD males in field cages. Preliminary trials have been conducted in laboratory and field cages in late 2020 and early 2021 and, in view of their small size and elusive behaviour, have pointed out many challenges. These preliminary data will facilitate the design of an efficient protocol adapted to SWD biology and easily transferable to FAO/IAEA Member States in the following months.

Preliminary trials to assess sterile male compatibility and competitiveness in field cages. The use of the plant Pyracantha coccinea allowed the observation of SWD sexual behaviour on fruits and leaves.

The efficiency of induction of SWD male sterility using X-rays has been also assessed. To this end, he is currently comparing the responses and the quality after exposure to X-rays and gamma rays.

The FAO/IAEA/USDA phytosanitary treatment project

The recommendation from the International Plant Protection Convention (IPPC) Technical Panel on Phytosanitary Treatments (TPPT) to remove the restriction of phytosanitary irradiation application against fruit flies for commodities stored in modified atmosphere was adopted during the fifteenth session of the Commission on Phytosanitary Measures (CPM-15) in 2021. Supporting results obtained by IPCL and USDA scientists, published in 2020, provided critical technical support for such recommendation. With the removal of the disclaimer 'This irradiation treatment should not be applied to fruits and vegetables stored in modified atmospheres' from nine PTs of the ISPM 28, phytosanitary irradiation against fruit flies can be broadly applicable.

Confirmatory tests evaluating the efficacy of a cold treatment against *Zeugodacus tau* have been conducted with 25,386 third instars and is nearly complete. Briefly, navel oranges infested with third instars *Z. tau* from Fujian, China, exposed to a temperature of 1.7ºC for 22 days yielded three survivors, one larva and two pupae, that did not emerge as adults. A manuscript summarizing the results from the comparative study with four *Z. tau* populations previously reported here and the current confirmatory test has been drafted and will be submitted for publication shortly.

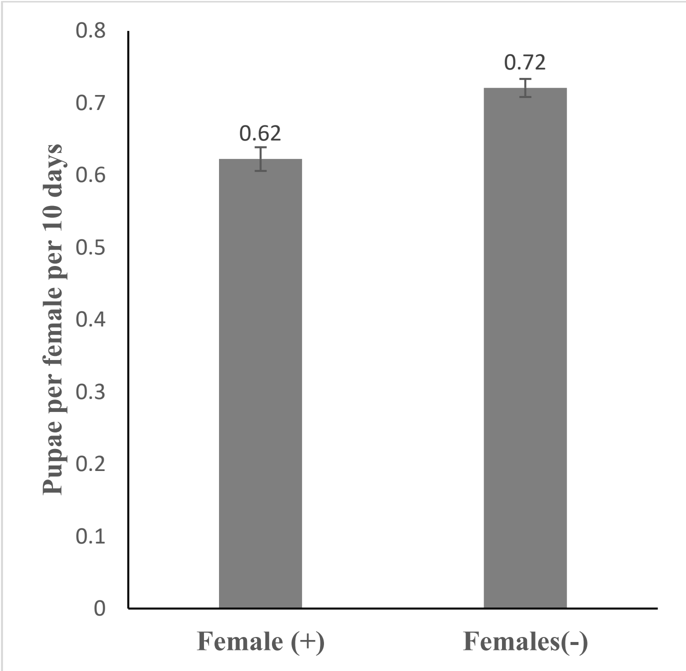
We continue evaluating physical and biological factors that could potentially affect the efficacy of phytosanitary irradiation. Regarding dose rate, our preliminary results suggest the absence of a dose rate effect in the irradiation treatment of 100 Gy for *Ceratitis capitata*. Only neglectable differences in emergence were observed with irradiation treatments of 20 and 30 Gy, suggesting that dose rate may not affect the efficacy of the phytosanitary irradiation dose used for *C. capitata*.

The controlled atmosphere temperature treatment system (CATTS) chamber donated by the USDA was commissioned and tested in April 2021, and it is now ready for operation. Research comparing the response of wild-collected and laboratory maintained *Bactrocera dorsalis* strains to vapour heat treatment has been initiated.

Livestock Pests

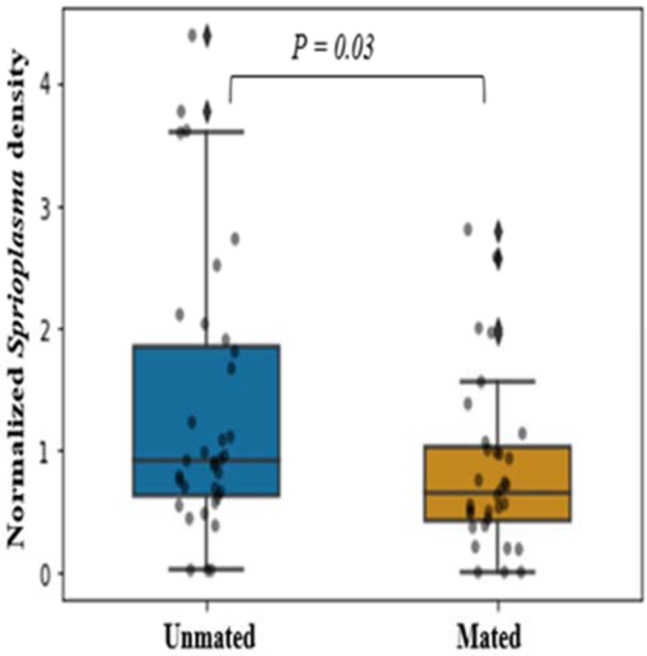
Analysis of the impact of *Spiroplasma* infection on the performance of *Glossina fuscipes fuscipes*

Tsetse flies are known to harbour a unique bacterial community mainly consisting of the obligate *Wigglesworthia glossinidia*, the commensal *Sodalis glossinidius*, and the widespread symbiont *Wolbachia pipientis*. Recently a fourth bacteria *Spiroplasma* was found to infect tsetse flies from the *palpalis* group. Tsetse flies from the *Glossina* *fuscipes fuscipes* colony maintained in the IPCL are infected with *Spiroplasma*.



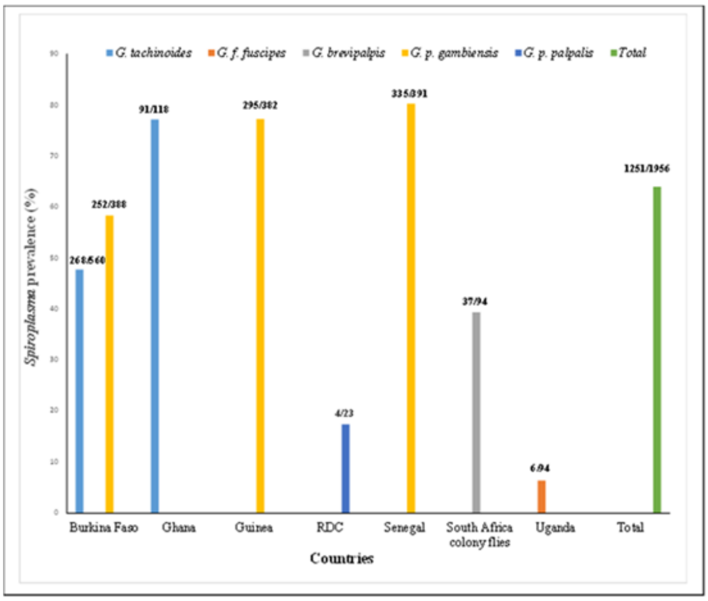
Impact of Spiroplasma infection on the productivity of Glossina fuscipes fuscipes.

The prevalence of *Spiroplasma* infection and its impact on the performance of the flies was analysed by Mr Kiswenda-Sida Mikhailou Dera, a PhD student from the Insectary of Bobo Dioulasso (IBD), Bobo Dioulasso, Burkina Faso. This research is carried out in collaboration with Prof Serap Aksoy and Dr Brian Weiss from Yale University, USA. The impact of *Spiroplasma* on the female productivity and the mating ability was determined and the results indicate that *Spiroplasma*-infected females produce lower number of pupae in comparison with uninfected females.



Normalized Spiroplasma *density in mated and unmated* Glossina fuscipes fuscipes *flies.*

The results also indicate that the pregnancy cycle in *Spiroplasma*-infected females was longer as compared with that of uninfected females. Moreover, unmated adults showed higher density of *Spiroplasma* than mated adults which might indicate that *Spiroplasma* reduced the mating ability of the adults. Analysing the insemination rate and the spermatheca fill indicated lower number of fully filled spermatheca with the seminal fluid in *Spiroplasma*-infected females as compared with uninfected females.



Prevalence of Spiroplasma *infection in wild tsetse populations of the* palpalis *group.*

The prevalence of *Spiroplasma* infection in wild tsetse population was determined by Mr Moustapha Dieng, a PhD student from Senegal and the results indicate high prevalence in *Glossina tachinoides* and *Glossina palpalis gambiensis* based on the use of primers to amplify the 16S rRNA gene. However, using other primers to genotype *Spiroplasma* strains indicated lower prevalence which might indicate different strains circulating in the tested populations. Genotyping and determining the number of *Spiroplasma* strains in the tested populations is currently in progress.

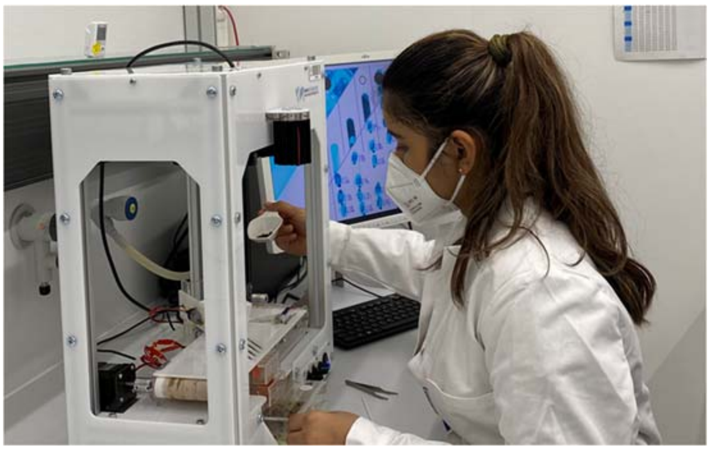
Operational use of the newly developed Near Infrared Pupal Sex Sorter (NIRPSS) in the SIT programme in Senegal.

The success of the SIT depends on the release of competitive, sterile males into the natural habitat of the species targeted for control. Systems that efficiently separate males from females during mass-production are needed as the release of sterile females will not contribute to the sterility in the field population and the females are needed for production. This is even more important in the case of tsetse. In contrast to most insects, female tsetse flies only produce a single larva in the uterus per ovulation cycle, resulting in very low fecundity. As a result of this low fecundity, all the females are needed for colony production and a non-destructive method of sex separation is needed. With the development of the Near InfraRed Pupae Sex Sorter

(NIRPSS), sex separation of *Glossina palpalis gambiensis* pupae is now possible.

The NIRPSS can sort up to 170 pupae per minute. The males can be separated from the female tsetse pupa five days before the emergence of the adults with an accuracy of 89%. Preliminary evaluation of the effect of NIRPSS on the quality of the males indicated that no significant wing damage could be found and that there was no negative effect on the male's ability to fly.

The sorter is currently in operation at the IPCL and at Scientica in Bratislava. It is used for the daily sorting of *G. p. gambiensis* pupae that are two times a week shipped long distance to the tsetse eradication programme in Senegal. As the pupae can now be sorted five days before emergence of the adults and can be shipped long distance without using low temperature conditions to prevent emergence, a 20% increase in male quality had been recorded in the sterile insects arriving at the Senegal programme.



Ms Syeda Dua Taqi sorting male Glossina palpalis gambiensis *pupae using the near infrared sex sorting machine for shipment to the SIT programme in Senegal.*

Human Disease Vectors

Predation propensity on laboratory-produced adult mosquitoes

A good understanding of the interactions between adult mosquito predators and laboratory-produced mosquitoes is important to better define the requirements of the SIT. The predation propensity of four mantis species (*Phyllocrania paradoxa*, *Hymenopus coronatus*, *Blepharopsis mendica*, *Deroplatys desiccate*) and two gecko species (*Phelsuma standingi, P. laticauda*), on adult *Aedes aegypti*, *Aedes albopictus* and *Anopheles arabiensis* mosquitoes were investigated under laboratory conditions. Mosquito characteristics including species, sex, chilling, marking did not affect their vulnerability to mantis predation. However, a high dose of irradiation (100 Gy – double the sterilizing dose) can lead to more vulnerable mosquitoes to mantis predation. Overall, the mantis species *B. mandica* showed more predacious capacities than the others. The gecko *P. standingi* preyed on all mosquitoes regardless of treatments with a relatively high predation rate. It was found to prefer eating *An. arabiensis* as compared with *Ae. aegypti* and *Ae. albopictus*. *Phelsuma laticauda* predated similarly on *Aedes* species but showed a preferred trend for *Ae. aegypti* as compared with *An. arabiensis*. Standardized predation trials may become useful additional quality control tools of irradiated mosquitoes within SIT programmes.

Blepharopsis mendica *eating a female* Aedes *mosquito (Photo credit: Thomas Wallner, FAO/IAEA).*

An assessment of the IPCL adult mass-rearing cage for *Aedes albopictus* and *Anopheles arabiensis*

Most mosquito-rearing facilities dedicated to SIT programs are currently developing improved tools and methods to enhance the capacity for mass-rearing the local mosquito strains in adequate numbers and are often limited by the inadequate size of readily available mosquito cages, which are commonly 30 × 30 × 30 cm or 60 × 60 × 60 cm. Mass-rearing and release facilities for *Aedes* mosquitoes are currently being built in several countries. Successful implementation of the SIT against *Ae. albopictus* and *An. arabiensis* relies on a continuous supply of sterile males. To meet this requirement, optimization of mass-rearing techniques is needed. The IPCL, in collaboration with MAPA Technology (Valencia, Spain), has recently developed a plexiglass mass-rearing cage (MRC) for *Ae. aegypti*. The MRC was tested for other species namely *An. arabiensis* and *Ae. albopictus*. The new MRC prototype is efficient in terms of egg production and can be used for mass-rearing in SIT programmes targeting *Ae. albopictus* as well as *An. arabiensis*. Although the new MRC has shown several advantages, further improvements are still ongoing to increase efficiency and stack ability of several cages in a mass-rearing facility.

Reports

Fifteenth Session of the Commission on Phytosanitary Measures (CPM), International Plant Protection Convention (IPPC), 16, 18 March and 1 April 2021 (held virtually)

The FAO Deputy Director-General Ms Beth Bechdol, in the opening remarks, assured the CPM that the FAO remains fully committed in its support to the IPPC community and the mission it shares with FAO in protecting the world's plant resources while also contributing to safe trade and environmental protection. She highlighted some of the landmark achievements of the past two years and thanked Finland for spearheading the proclamation of the International Year of Plant Health (IYPH).

The keynote address was delivered by the Finnish Minister of Agriculture and Forestry, Mr Jari Leppä, who reflected on the impact and legacy of the events of the past year for plant health. The Minister recalled the original proposal by Finland to celebrate the year 2020 as the IYPH, and the ambitious plans of Finland, the FAO and the IPPC community that followed. The aim had been to establish an understanding around the world that plant health is as important for the environment and livelihoods as human health is to the well-being of people.

On issues related with the Insect Pest Control Subprogramme, the CPM-15:

- adopted the revision of ISPM 8 (Determination of pest status in an area) and revoked the previously adopted version;
- ISPM 44 (Requirements for the use of modified atmosphere treatments as phytosanitary measures);
- the Standards Committee adopted on behalf of the CPM one diagnostic protocol (DP) as an annex to ISPM 27 (Diagnostic protocols for regulated pests): DP 29 (*Bactrocera dorsalis*);
- adopted seven phytosanitary treatments (PT) as Annex to ISPM 28 (Phytosanitary treatments for regulated pests):
    - PT 33 (Irradiation treatment for *Bactrocera dorsalis*) (2017-015) as Annex 33 to ISPM 28;
    - PT 34 (Cold treatment for *Ceratitis capitata* on *Prunus avium*, *Prunus salicina* and *Prunus persica*) as Annex 34 to ISPM 28;
    - PT 35 (Cold treatment for *Bactrocera tryoni* on *Prunus avium*, *Prunus salicina* and *Prunus persica*) as Annex 35 to ISPM 28;
    - PT 36 (Cold treatment for *Ceratitis capitata* on *Vitis vinifera*) as Annex 36 to ISPM 28;
    - PT 37 (Cold treatment for *Bactrocera tryoni* on *Vitis vinifera*) as Annex 37 to ISPM 28;
    - PT 38 (Irradiation treatment for *Carposina sasakii*) as Annex 38 to ISPM 28;
    - PT 39 (Irradiation treatment for the genus *Anastrepha*) as Annex 39 to ISPM 28

*Mexican fruit fly (*Anastrepha ludens*).*

- Ink amendments to the following Annexes to ISPM 28 on tephritid fruit flies were also adopted by CPM-15, including the two irradiation treatments adopted at the CPM-15 (PT 33 and PT 39):
    - PT 1 (Irradiation treatment for *Anastrepha ludens*);
    - PT 2 (Irradiation treatment for *Anastrepha obliqua*);
    - PT 3 (Irradiation treatment for *Anastrepha serpentina*);
    - PT 4 (Irradiation treatment for *Bactrocera jarvisi*);
    - PT 5 (Irradiation treatment for *Bactrocera tryoni*);
    - PT 7 (Irradiation treatment for fruit flies of the family Tephritidae (generic));
    - PT 14 (Irradiation treatment for *Ceratitis capitata*);
    - PT 33 (Irradiation treatment for *Bactrocera dorsalis*);
    - PT 39 (Irradiation treatment for the genus *Anastrepha*).

Those ink amendments included the removal of the disclaimer "This irradiation treatment should not be applied to fruits and vegetables stored in modified atmospheres" recommended by the Technical Panel on Phytosanitary Treatments (TPPT) based on studies showing that irradiation in modified atmospheres with doses approved as phytosanitary treatments does not reduce treatment efficacy.

The Sun Yat-Sen University Designated as an IAEA Collaborating Centre

The Sun Yat-Sen University (SYSU), China, has been designated as an IAEA Collaborating Centre for the period 2021–2024 in relation to its programmes to combat the disease-transmitting *Aedes* mosquitoes. The SYSU, in collaboration with the company Wolbaki, and with the support of the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture implemented between 2015 and 2017 an incompatible insect technique/sterile insect technique (IIT/SIT) pilot trial against *Aedes albopictus* on two islands in Guangzhou with a total target area of 30 ha. During the pilot trial, about 100 000 sterile male mosquitoes were routinely released per week. In 2016–2017, the wild mosquito population was suppressed more than 95%. The SYSU was also instrumental in the development of new equipment, that improved the efficiency of the mass-rearing of *Ae. albopictus*, e.g. automatic sex separator.

Sun Yat-Sen University Collaborating Centre Designation Ceremony: Mr Rafael Mariano Grossi, IAEA Director General witness Ms Najat Mokhtar, IAEA Deputy Director General, Department of Nuclear Sciences and Applications handover the plaque of collaborating centre to Mr Sen Li, Minister Counsellor, Permanent Mission of China to the IAEA in Vienna.

The main mandate of the SYSU with respect to the objectives of the collaborating centre, is to contribute to the development of the SIT for *Ae. albopictus* to facilitate the sustainable and environment-friendly control of this important vector of major human diseases. The SYSU will continue to be a driving force in the Asian region with respect to promoting the SIT for *Aedes* mosquitoes, will be an important centre for the training of technical staff in all aspects of the SIT for mosquitoes, and will continue to host important meetings and training courses.

WHO Stakeholders Meeting on Human African Trypanosomiasis (HAT) Elimination, 1–3 June 2021 (virtual)

The meeting was held virtually and counted with the participation of relevant stakeholders such as WHO, National Sleeping Sickness Control programs focal points, academic and research institutions, donors, public and private partners, NGOs, and International Organizations. The main purpose of the meeting was to review the epidemiological situation of gambiense-HAT and rhodesiense-HAT diseases and to update the global progress achieved on the elimination of these diseases in 2020 as a public health problem. The WHO reported that the area at risk has been significantly reduced (83%). However, this reduction is slightly below the targeted figure of 90%. There are still 55 million of people at risk of contracting the disease but only three million are exposed to hight risk. According to the WHO, around two million people are actively screened every year, however there was a decrease in active screening in all endemic countries in 2020 due to the COVID-19 pandemic.

In addition, the pandemic disrupted community activities, drug delivery, supervisory visit, and support from the national level. Nevertheless, adaptative strategies such as virtual meetings, adapted active screening and reinforcement of passive screening were implemented to limit the impact of the pandemic on the process of HAT elimination. In 2020, 663 new HAT cases were detected as compared to 992 detected cases in 2019. This shows an outstanding reduction as 32 000 new cases were detected in 2000. During the meeting good progress was also reported on HAT treatment and diagnostics, innovation in surveillance and control tools, HAT Atlas, and vector control. It is clear that vector control plays an integrated part in the progress against HAT, and active vector control is conducted in 14 countries in the gambiense-HAT and rhodesiense-HAT diseases areas. In addition, WHO presented and discussed with the participating stakeholders the new goals and the strategies to be implemented targeting the interruption of HAT transmission in 2030 including potential challenges.

Announcements

Publication on 'Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management' (2nd edition)

The sterile insect technique (SIT) is an environment-friendly method of pest control that integrates well into area-wide integrated pest management (AW-IPM) programmes. This book takes a generic, thematic, comprehensive, and global approach in describing the principles and practice of the SIT. The strengths and weaknesses, and successes and failures, of the SIT are evaluated openly and fairly from a scientific perspective. The SIT is applicable to some major pests of plant-, animal- and human-health importance, and criteria are provided to guide in the selection of pests appropriate for the SIT.

In the second edition all aspects of the SIT have been updated and the content considerably expanded. A great variety of subjects is covered, from the history of the SIT to improved prospects for its future application. The major chapters discuss the principles and technical components of applying sterile insects. The four main strategic options in using the SIT — suppression, containment, prevention, and eradication — with examples of each option are described in detail. Other chapters deal with supportive technologies, economic, environmental, and management considerations, and the socio-economic impact of AW-IPM programmes that integrate the SIT. In addition, this second edition includes six new chapters covering the latest developments in the technology: managing pathogens in insect mass-rearing, using symbionts and modern molecular technologies in support of the SIT, applying post-factory nutritional, hormonal, and semiochemical treatments, applying the SIT to eradicating outbreaks of invasive pests, and using the SIT against mosquito vectors of disease.

The PDF version of this book is freely available and can be accessed and downloaded at:
https://doi.org/10.1201/9781003035572.

Publication on 'Area-Wide Integrated Pest Management: Development and Field Application'

Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, including non-target species, air, water and soil. The extensive reliance on insecticide use reduces biodiversity, contributes to pollinator decline, destroys habitat, and threatens endangered species. This book offers a more effective application of the integrated pest management (IPM) approach, on an area-wide (AW) or population-wide (AW-IPM) basis, which aims at the management of the total population of a pest, involving a coordinated effort over often larger areas. For major livestock pests, vectors of human diseases and pests of high-value crops with low pest tolerance, there are compelling economic reasons for participating in AW-IPM.

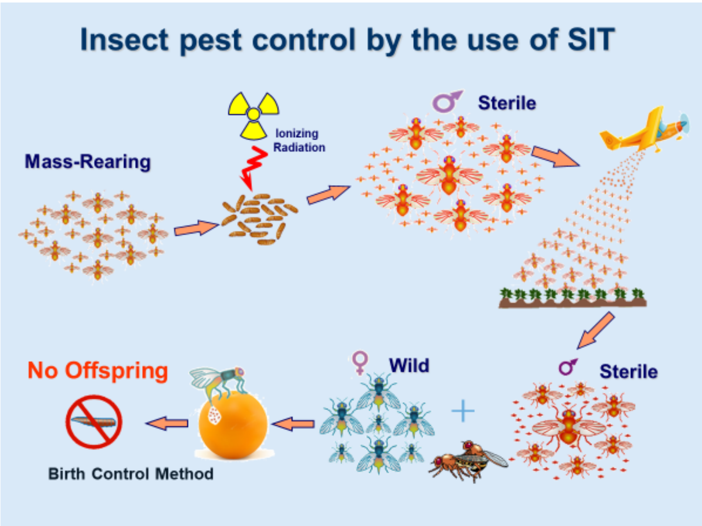
This new textbook attempts to address various fundamental components of AW-IPM, e.g. the importance of relevant problem-solving research, the need for planning and essential baseline data collection, the significance of integrating adequate tools for appropriate control strategies, and the value of pilot trials, etc. With 48 chapters authored by 184 experts from more than 31 countries, the book includes many technical advances in the areas of genetics, molecular biology, microbiology, biological control, resistance management, modelling, automated surveillance and unmanned aerial release systems, and as well as the social sciences that facilitate the planning and implementing of area-wide strategies.

The book is essential reading for the academic and applied research community as well as national and regional government plant and human/animal health authorities with responsibility for protecting plant and human/animal resources.

The PDF version of this book is freely available and can be accessed and downloaded at:
https://doi.org/10.1201/9781003169239.

Special Issue on 'Sterile Insect Technique (SIT) and its Applications'

Insects represent perhaps the most successful group of animals in the tree of life. Their evolutionary success is reflected in their large biomass and large number of species. Most of them are important for the health and proper functioning of the terrestrial and aquatic ecosystems. However, a few of them are considered as major agricultural pests and human disease vectors and their populations require rational and sustainable control. The sterile insect technique (SIT), as a component of area-wide integrated pest management (AW-IPM) approaches, has been successfully used to manage insect pest populations during the last six decades in a species-specific and environment-friendly manner.



During the last years, significant progress has been achieved in the development, refinement and implementation of the SIT package including mass-rearing, irradiation, sex separation, shipment, handling, packaging and release of sterile insects as well as the pre- and post-release monitoring of insect populations and product and process quality control.

Some of the recent achievements as well as challenges in the SIT are presented in the journal 'Insects' Special Issue on 'Sterile insect technique (SIT) and its applications' (https://www.mdpi.com/journal/insects/special_issues/mr_sit). The Special Issue is already closed to additional submissions and currently includes 26 papers (19 original research articles and 7 reviews) and 2 manuscripts still under review, covering a wide array of components of the SIT package and focusing on all main groups of SIT target species: plant and livestock pests, and human disease vectors.

NEWSFLASH: A New Feature of the Tephritid Workers Database (TWD)

The Insect Pest Control Subprogramme (IPCS) is currently actively working to improve the IPCS hosted databases, including the TWD, to help and encourage knowledge sharing among Member States for capacity building and technical assistance.

In this effort, IPCS has developed the Newsflash, a new information service for the Tephritid fruit fly workers around the world. Subscribe to the Newsflash to start receiving the latest breaking news delivered directly to your inbox, so you will not miss important events. You may wish to invite your colleagues and students to subscribe if they are not already on TWD/Fruit Fly News mailing list. Subscribe and unsubscribe links are available at the TWD News and within the Newsflash messages: https://nucleus.iaea.org/sites/naipc/twd/Lists/News/News View all.aspx.

Map of the registered Tephritid fruit fly workers around the world

11th International Symposium on Fruit Flies of Economic Importance

The 11th International Symposium on Fruit Flies of Economic Importance (11th ISFFEI) will be hosted by NSW Department of Primary Industries on 14–18 November 2022, in Sydney, Australia. The symposium will become host to scientists, researchers, and those involved in plant protection agencies and phytosanitary operational programs, to share knowledge, technologies and experiences regarding fruit flies. For more information: https://www.11isffei.com/

Other News

How Science Wiped Out the Invasive Pink Bollworm in the United States

The very hungry caterpillars emerged from their eggs and bored into nearby cotton bolls, sinking their mouthparts into cottonseeds and blocking production of valuable lint as they burrowed through the bolls in their quest to tank up before their final molt. That was bad news for the cotton industry—starting in 1917 when the invasive pink bollworm (*Pectinophora gossypiella*) first showed up in the United States.

The pink bollworm moth is about one-third of an inch long in its adult form, shown here on a cotton boll. The invasive pest first showed up in the United States in 1917, and it ravaged cotton for decades before a combination of transgenic cotton and sterile insect releases helped to eradicate it a century later. (Photo by Alexander Yelich, University of Arizona).

Arizona cotton growers lost $32 million due to crops damaged by the pink bollworm in 1990. They spent another $16 million on insecticides to control the pest, but those can't really reach the caterpillars protected inside the bolls. In 1996, Bt cotton hit the market. This genetically engineered crop produces insecticidal proteins from a bacterium (*Bacillus thuringiensis*, or Bt), so when susceptible insects—like pink bollworm larvae—chomp down on that cotton, they don't survive the meal.

That made a huge difference in controlling the pest, but researchers knew the clock was ticking. Pink bollworm larvae rapidly evolved resistance to Bt cotton in the laboratory and in cotton fields in India.

What happened next—a coordinated eradication program that wiped out the pink bollworm in the cotton-growing regions of the United States—is featured in the January 5 issue of Proceedings of the National Academy of Sciences.

"I wanted to make sure that this great success of collaboration between farmers and entomologists took its place in the history books and the textbooks," says Bruce Tabashnik, Ph.D., head of the Department of Entomology at the University of Arizona and lead author of the article.

A Not-So-Modest Proposal

When Tabashnik first heard about the eradication proposal nearly two decades ago, he wasn't a fan of the idea. "I thought it wouldn't work," he says, chuckling. "The adaptability of insects is one of the reasons they're so difficult to control, manage, and—particularly—eradicate. So, when I knew that the growers in Arizona were thinking about this, it made me very anxious, because at that point things were being managed well in Arizona."

Tabashnik agreed to run the computer models—fully expecting the math to quash the idea—but the results immediately won him over. "Anything we did that was realistic worked," he explains. "So, I changed sides and became an advocate."

The next step was convincing the Environmental Protection Agency (EPA). At that time, the EPA required farmers to plant areas of regular cotton called refuges so that any Bt-resistant moths would be more likely to mate with susceptible moths. However, the new plan would work best if farmers could plant all Bt cotton.

*The invasive pink bollworm (*Pectinophora gossypiella*) first showed up in the United States in 1917, and it ravaged cotton for decades before a combination of transgenic cotton and sterile insect releases helped to eradicate the pest a century later. (Photo by Alexander Yelich, University of Arizona).*

They paired that with another strategy called sterile insect release. In a facility in Phoenix, scientists bred pink bollworms and zapped the adults with radiation to render them sterile. Then, pilots flew over cotton fields, releasing scads of these sterile moths so they outnumbered wild type moths, making it tough to find a fertile mate.

Over the course of the eradication project, from 2006 to 2014, they dropped 11 billion sterile moths over Arizona cotton fields. For the first two years, those steriles outnumbered the wild moths by 2-to-1, which was enough to set off a cascade that ballooned to 2 000-to-1 by 2010. "When you get 2 000 steriles to one wild insect, it's really hard for the wild population to sustain itself," says Tabashnik. "2012 was the last year a wild pink bollworm moth was caught in Arizona. One was caught, and the ratio was 600 000 steriles to that one."

Parallel programs ran in the rest of the region: California, New Mexico, Texas, and portions of Mexico. The Pink Bollworm Technical Advisory Committee, which included Tabashnik, wanted to see four consecutive years with zero pink bollworm catches before considering the pest eradicated. The United States Department of Agriculture (USDA) made that declaration official in 2018—a century after the pink bollworm problem first showed up.

*As part of a multifaceted program that eradicated the invasive pink bollworm (*Pectinophora gossypiella*) from the United States and Mexico, the caterpillars of this devastating cotton pest were mass-reared (as seen above) and 11 billion sterile moths were released by airplanes to overwhelm its populations in the field. (Photo by Alexander Yelich, University of Arizona).*

Success Story

Pink bollworm eradication saved the Unites States farmers $192 million between 2014 and 2019. It's a feat that required careful coordination between scientists working in the cotton industry, government, and academia. It helped that pink bollworm caterpillars depend almost entirely on cotton as a host plant and that their Bt resistance is inherited recessively—but it's possible the strategy could work for other pests too.

Because the pink bollworm is still thriving in dozens of other countries and global markets are so interconnected, Tabashnik thinks reintroduction of the pest is likely. They'll monitor continuously and keep an arsenal of interventions at the ready. And there are other Bt toxins that kill resistant pink bollworm that could be engineered into cotton in the future.

Tabashnik hopes the story serves as a guidepost for other complex problems facing society. "It's a great example of putting science to work to achieve something that benefits everybody," he says.

Read More: "Transgenic cotton and sterile insect releases synergize eradication of pink bollworm a century after it invaded the United States" at Proceedings of the National Academy of Sciences.
https://www.pnas.org/content/118/1/e2019115118

Source: Entomology Today. Melissa Mayer. 16 February 2021. (https://entomologytoday.org/2021/02/16/how-science-wiped-out-invasive-pink-bollworm-united-states/).

Releasing Research on Sterile Insect Release in the United States

Michigan team studying sterile insect release in two states

Drones now drop sterile codling moths over thousands of acres of apples in Washington, but two leading tree fruit entomologists continue research efforts aimed at fine-tuning the use of sterile insects by optimizing delivery methods and timings.

Rob Curtiss, a Michigan State University graduate student, releases sterile codling moths by hand in a netted orchard near Wenatchee, Washington. He's still figuring out if you need to be gentle with the sterile moths when releasing them by hand, or if you can just toss them and go on your way. (Courtesy Rob Curtiss/Michigan State University).

Larry Gut of Michigan State University (MSU) and Betsy Beers of Washington State University (WSU) discussed their findings on delivery methods and rates at industry meetings and with Good Fruit Grower this winter.

Gut's trials look at whether insects should be distributed uniformly throughout the orchard or from a single release point near the center. He's also weighing drone versus hand delivery.

Drones are efficient and quick, but moths appear more likely to stay within the boundaries of the orchard when distributed by hand. Gut found moth recapture is more efficient when the drone hovers closer to the tree canopy, about 15 meters above the ground. The higher the drone goes, the lower the rate of recapture, he said.

The sterile moths come from a Canadian facility that irradiates them with cobalt. The sterile males compete with wild males, and the programme's aim is to eliminate fertile matings and, thus, offspring. So far, Rob Curtiss, an MSU graduate student working with Gut, is studying sterile insect release near Wenatchee, Washington. He's been working with Gut since 2018. They decided Curtiss would do his research in Washington because of easier access to sterile moths.

These sterile moths, covered in fluorescent dye, have fallen onto leaves while they are still cold after release. The moths start to move around when they warm up and are most active around sunset. Curtiss covers them in dye to differentiate them from other codling moths. (Courtesy Rob Curtiss/Michigan State University).

There's still a lot of research to do, but Curtiss thinks sterile insect release has potential in Michigan as well as Washington, despite the different environments, disease pressures and costs. Here are some of his takeaways so far:

Sterile moths are mobile and can quickly distance themselves throughout an orchard when using both hand and drone release methods.

Single-point releases from the center of a 10-acre block are effective at ensuring moths get to the edges of the block.

He found moths released via drone have a higher recovery rate than those released by hand.

He also found a higher recovery rate of sterile moths from trellised, high-density orchards than from older, low-density plantings.

Sterile moths released in low numbers still have a measurable impact on wild populations.

In orchards with pheromone mating disruption in place, moths only move about half as far as in other orchards.

Beers, a WSU entomologist, shared findings from her research trials that illustrate both the potential and the remaining questions about how best to use sterile insect release.

She successfully eliminated hot spots after three years of treatments in commercial blocks, and fruit damage steadily declined in most of the test blocks over the three years. "The success of Sterile Insect Releases (SIR) will depend on the grower's ability to put all the components together," she said.

The commercialization of drone release and the research comes at a pivotal time in codling moth management history. The pest has anecdotally been on the rise in the Northwest, and the industry has formed a codling moth task force that is conducting grower surveys.

Source: Good Fruit Grower. Matt Milkovich and Ross Courtney. 3 March 2021 (https://www.goodfruit.com/releasing-research-on-sterile-insect-release/).

Queensland Fruit Fly Successfully Eradicated from the Perth Metropolitan Area, West Australia

The Queensland fruit fly (Qfly), *Bactrocera tryoni*, pest has been eradicated from Perth's western suburbs following concerted efforts by the Department of Primary Industries and Regional Development (DPIRD) and the local community. The DPIRD initiated a dedicated response following an outbreak of Qfly in Dalkeith and surrounds in March 2020.

Quarantine measures were put in place to stop the spread of the pest, which involved 13 500 premises across Dalkeith, Nedlands, Claremont and surrounding suburbs, and required residents to restrict the movement of Qfly host fruit. The DPIRD chief plant biosecurity officer Sonya Broughton said these measures were no longer required and had been lifted.

"Restrictions on the management and movement of Qfly susceptible fruit and vegetables for this area have been removed," Dr Broughton said. She said DPIRD was currently working to eradicate a separate, recent outbreak of Qfly in the Coolbellup area, with community members in this area encouraged to support control efforts and adhere to required measures in that area.

The Qfly attacks a wide range of fruits and fruiting vegetables. It is found in parts of eastern Australia, however, it is not established in WA. During the 10-month response campaign in the western suburbs, 20 000 baits and traps were deployed, 170 000 property inspections undertaken, 32 tonnes of fruit collected and more than 30 million sterile flies released. At the height of the eradication effort, more than 200 response personnel were on the ground conducting inspection and control activities.

Queensland fruit fly has been eradicated from certain areas of Perth's western suburbs in Australia.

"The successful eradication of Qfly from Dalkeith and surrounds is vital in supporting our State's valuable horticultural industries," Dr Broughton said. "I commend all those involved in the response for their diligence and hard work". "I particularly acknowledge the excellent support from the local community, including residents and businesses who allowed inspectors to access their properties, restricted movement of host fruit and properly disposed of any waste fruit. "While restrictions for this area have lifted, it is important for community members to continue to maintain overall garden hygiene and be on the lookout for any usual pests".

Source: Farm Weekly, Western Australia, 6 Feb 2021. (https://www.farmweekly.com.au/story/7113996/queensland-fruit-fly-successfully-eradicated/).

The South Australia to Release Millions of Sterile Fruit Flies in Bid to Battle Outbreak

The South Australian (SA) government will unleash close to 100 million sterile fruit flies from the sky in a bold plan to try and eradicate the critters plaguing numerous suburbs. The Sterile Insect Technique (SIT) flies will be released from a low-flying fixed wing aeroplane across 11 outbreak areas spanning across metropolitan Adelaide and Renmark.

The programme, under which 90 million 'attractive' male insects will be released, will begin on Saturday 3 April 2021 and run over ten weeks with flights twice weekly.

Primary Industries and Regional Development Minister David Basham said the sterile flies were the SA government's "latest weapon in our armoury". "These sterile flies are bred to be strong, fit, and very attractive to the wild fruit flies," Mr Basham said. "The sterile flies will breed with the wild flies meaning they can't reproduce, and we break the life cycle." He urged residents: "Don't be alarmed if you see this plane flying low over your suburb."

The South Australian Government will unleash almost 100 million sterile fruit flies to eradicate the pest that threatens the state's $1.3 billion horticulture industry. (Photo: Keryn Stevens Source: News Corp Australia).

"This is an important step as we continue our eradication programme to protect the thousands of jobs and hundreds of businesses threatened by these outbreaks."

More than 400 department staff have begun baiting and fruit stripping operations across the outbreak areas. The eradication efforts have cost the state government almost $20 million to date.

The Department of Primary Industries and Regions (PIRSA) biosecurity officers have been door knocking residents and offering assistance to strip ripe fruit off their trees to help stop the spread of fruit fly. (Photo: Keryn Stevens Source: News Corp Australia).

Mr Basham reminded South Australians to continue following 'strict' quarantine rules in a bid to protect the state's $1.3 billion horticulture industry. "If you live in an outbreak area you must not move fruit and vegetables off your property, especially over the Easter long weekend and school holidays as many South Australians travel around the state," he said. "This is a reminder to keep your garden tidy by picking fruit as soon as it is ripe, collecting fallen fruit from the ground, and disposing of it correctly according to where you live."

Efforts to contain the flies sparked some confusion and outrage at the beginning of the school year when parents and caregivers were told they could not pack certain fruits and vegetables in lunch boxes because of the severity of the outbreak. Restrictions across all 11 outbreaks are expected to remain in place until at least 18 December 2021.

Source: News.Com.Au. Emily Cosenza. 3 April 2021. (https://www.news.com.au/lifestyle/food/sa-to-release-millions-of-sterile-fruit-flies-in-bid-to-battle-outbreak/news-story/282cac6f41f99a21f3fe0a4d153250f8/).

Sterile Insect Technique Programme against *Ceratitis capitata* in the Valencian Community (Spain)

The Mediterranean fruit fly *Ceratitis capitata* is considered one of the most damaging pests worldwide. In Spain, it has been present since the 19th century and has made serious economic damage to the national fruit industry.

In the Valencian Community, the leading region in citrus production in Spain and the first exporter of citrus fruits for fresh consumption in the world, the Department of Agriculture has been promoting and leading an area-wide integrated pest management (AW-IPM) programme against Mediterranean fruit fly since the 1960s. In the past, mainly aerial and ground insecticide treatments were applied. Since 2007, the AW-IPM programme, operated by the state-owned company 'Grupo TRAGSA', the insecticide treatments have been drastically reduced and replaced by other environmental-friendly pest control methods.

Mediterranean fruit fly mass-rearing facility, Caudete de las Fuentes, Valencia (Spain), with a production capacity of 500 million sterile males per week.

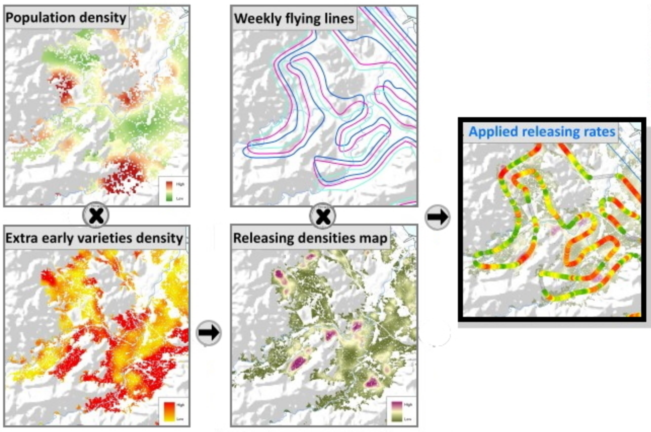
The sterile insect technique (SIT) has become the main tool to control the Mediterranean fruit fly. Complementary activities such as mass-trapping, aerial and/or ground treatments using organic insecticide, installation of traps in isolated fruit trees to control hotspots, etc. are also carried out in specific places and at specific times if a wild population hotspot is detected.

Every year, more than 12 000 million sterile males are released by air on 140 000 hectares of citrus production area in the Valencian Community. These sterile males are produced in the mass-rearing facility located in Caudete de las Fuentes (Valencia), the second largest in the world (after El Pino – Guatemala), with a production capacity of 500 million sterile males per week.

The Mediterranean fruit fly population dynamics and sterile:wild ratio are monitored through captures in more than 1 200 traps of a monitoring network. These traps, inspected on a weekly basis, are georeferenced and distributed throughout the citrus-growing area of the Valencia Community.

The GIS information is available, and data about the citrus variety in each plot of the region is known. This allows to analyse information spatially in a GIS and to determine the abundance of susceptible citrus varieties in each zone according to the period of the year.

Depending on the level of the wild population and the season, the number of sterile insects released is adjusted for each polygon. The release dosage of sterile insects is set based on a risk map obtained by crossing the information from the trap monitoring network and the respective state of the citrus varieties in the area.



Example of procedure for obtaining the risk map and the variable-rate release path (map on the right).

As a result of this AW-IPM Programme, the area treated with insecticides by aerial means has been reduced by more than 93% in the last 15 years. In addition, official data indicates that the trend in citrus exports and their economic importance is clearly positive for the Valencia Community and that revenues have increased by more than 27% since 2005.

Source: Ignacio Pla Mora, Carles Tur (TRAGSA) and Vicente Dalmau (Department of Agriculture of Valencia).

Relevant Published Articles

Transgenic Cotton and Sterile Insect Releases Synergize Eradication of Pink Bollworm a Century after it Invaded the United States

Bruce E. Tabashnik[a], Leighton R. Liesner[b], Peter C. Ellsworth[c], Gopalan C. Unnithan[a], Jeffrey A. Fabrick[d], Steven E. Naranjo[d], Xianchun Li[a], Timothy J. Dennehy[a], Larry Antilla[b], Robert T. Staten[e], and Yves Carrière[a]

[a]*Department of Entomology, University of Arizona, Tucson, AZ 85721;*
[b]*Arizona Cotton Research and Protection Council, Phoenix, AZ 85040;*
[c]*Department of Entomology, University of Arizona, Maricopa, AZ 85138;*
[d]*US Arid Land Agricultural Research Center, Agricultural Research Service, US Department of Agriculture, Maricopa, AZ 85138;*
[e]*Animal and Plant Health Inspection Service, US Department of Agriculture, Phoenix, AZ 85040*

Abstract

Invasive organisms pose a global threat and are exceptionally difficult to eradicate after they become abundant in their new habitats. We report a successful multitactic strategy for combating the pink bollworm (*Pectinophora gossypiella*), one of the world's most invasive pests. A coordinated program in the southwestern United States and northern Mexico included releases of billions of sterile pink bollworm moths from airplanes and planting of cotton engineered to produce insecticidal proteins from the bacterium *Bacillus thuringiensis* (Bt). An analysis of computer simulations and 21 y of field data from Arizona demonstrate that the transgenic Bt cotton and sterile insect releases interacted synergistically to reduce the pest's population size. In Arizona, the program started in 2006 and decreased the pest's estimated statewide population size from over 2 billion in 2005 to zero in 2013. Complementary regional efforts eradicated this pest throughout the cotton-growing areas of the continental United States and northern Mexico a century after it had invaded both countries. The removal of this pest saved farmers in the United States $192 million from 2014 to 2019. It also eliminated the environmental and safety hazards associated with insecticide sprays that had previously targeted the pink bollworm and facilitated an 82% reduction in insecticides used against all cotton pests in Arizona. The economic and social benefits achieved demonstrate the advantages of using agricultural biotechnology in concert with classical pest control tactics.

The full paper was published in: PNAS 2021 Vol. 118 No. 1 e2019115118 https://www.pnas.org/content/118/1/e2019115118.

Mosquito Sexual Selection and Reproductive Control Programs

Lauren J. Cator[1], Claudia A.S. Wyer[1,3], Laura C. Harrington[2]

[1] *Department of Life Sciences, Imperial College London, Ascot, UK*
[2] *Department of Entomology, Cornell University, Ithaca, New York, NY, USA*
[3] *Science and Solutions for a Changing Planet DTP, Kensington, London SW7 2AZ, UK*

Abstract

The mating systems of medically important mosquitoes are characterized by aerial swarms, within which many complex behaviors unfold.

Evidence suggests that females mate once, whereas males can mate multiply.

This combined with swarms that consist of many more males than females generates intense mating competition between males and allows females to be choosy.

A lack of data on male and female sexually selected traits and evolutionary relationships between them are a key knowledge gap in these systems.

A comprehensive understanding of mosquito mating biology is essential for the development and successful deployment of reproductive control methods.

The field of mosquito mating biology has experienced a considerable expansion in the past decade. Recent work has generated many key insights about specific aspects of mating behavior and physiology. Here, we synthesize these findings and classify swarming mosquito systems as polygynous. Male mating success is highly variable in swarms and evidence suggests that it is likely determined by both scramble competition between males and female choice. Incorporating this new understanding will improve both implementation and long-term stability of reproductive control tools.

The full paper was published in: Trends in Parasitology, Volume 37, Issue 4, 2021, Pages 330-339, ISSN 1471-4922, https://www.sciencedirect.com/science/article/pii/S147149222030324X.

Tephritid Fruit Fly Semiochemicals: Current Knowledge and Future Perspectives

Francesca Scolari [1,*], Federica Valerio [2], Giovanni Benelli [3], Nikos T. Papadopoulos [4] and Lucie Vaníčková [5,*]

[1] Institute of Molecular Genetics IGM-CNR "Luigi Luca Cavalli-Sforza", I-27100 Pavia, Italy
[2] Department of Biology and Biotechnology, University of Pavia, I-27100 Pavia, Italy
[3] Department of Agriculture, Food and Environment, University of Pisa, via del Borghetto 80, 56124 Pisa, Italy
[4] Department of Agriculture Crop Production and Rural Environment, University of Thessaly, Fytokou st., N. Ionia, 38446 Volos, Greece
[5] Department of Chemistry and Biochemistry, Mendel University in Brno, Zemedelska 1, CZ-613 00 Brno, Czech Republic
[*] Authors to whom correspondence should be addressed.

Abstract

The Dipteran family Tephritidae (true fruit flies) comprises more than 5000 species classified in 500 genera distributed worldwide. Tephritidae include devastating agricultural pests and highly invasive species whose spread is currently facilitated by globalization, international trade and human mobility. The ability to identify and exploit a wide range of host plants for oviposition, as well as effective and diversified reproductive strategies, are among the key features supporting tephritid biological success. Intraspecific communication involves the exchange of a complex set of sensory cues that are species- and sex-specific. Chemical signals, which are standing out in tephritid communication, comprise long-distance pheromones emitted by one or both sexes, cuticular hydrocarbons with limited volatility deposited on the surrounding substrate or on the insect body regulating medium- to short-distance communication, and host-marking compounds deposited on the fruit after oviposition. In this review, the current knowledge on tephritid chemical communication was analysed with a special emphasis on fruit fly pest species belonging to the *Anastrepha, Bactrocera, Ceratitis*, and *Rhagoletis* genera. The multidisciplinary approaches adopted for characterising tephritid semiochemicals, and the real-world applications and challenges for Integrated Pest Management (IPM) and biological control strategies are critically discussed. Future perspectives for targeted research on fruit fly chemical communication are highlighted.

The full paper was published in: Insects 2021, 12, 408. https://doi.org/10.3390/insects12050408

Stable Isotopes for Reliable Identification of Wild and Mass-reared Queensland Fruit Flies in Sterile Insect Technique Programs

B. Mainali[1], A. S. Andrew[3], P. W. Taylor[1] & P. Rempoulakis[1,2]

[1] Applied BioSciences, Macquarie University, Sydney, NSW, 2109, Australia
[2] NSW Department of Primary Industries, Ourimbah, NSW, 2258, Australia
[3] Earth and Environmental Sciences, Macquarie University, Sydney, NSW, 2109, Australia

Abstract

Queensland fruit fly is one of the most economically important horticultural pests in Australia. Sterile insect technique (SIT) is now being reconsidered and upscaled to combat this pest so reliable discrimination of released sterile Q-flies from wild flies in monitoring traps is important for effective SIT operations. Stable isotopes provide a permanent chemical marker to discriminate sterile and wild flies when dye marking is unclear. In this study, we compared the isotopic ratios of carbon and nitrogen between Q-flies reared on different larval diets and wild flies collected from diverse locations in Australia and New Caledonia. Finally, we conducted a release–recapture study to corroborate differences in stable isotope C and N ratios in laboratory-reared and wild Q-flies. The δ^{15}N values obtained from wild and laboratory Q-flies showed high variability that is likely related to the food source of the larval and/or adult stage and do not offer an effective means to discriminate between sterile and wild Q-flies. The δ^{13}C values of examined wild Q-flies ranged from − 27.46 to − 24.37‰ VPDB, whereas those from laboratory-reared, released and recaptured Q-flies ranged from − 25.73 to − 19.26‰ VPDB. Differences in δ^{13}C values resulted in 100% correct classification of wild flies and 96.88% correct classification of released flies. Measurements of intrinsic δ^{13}C values offer a precise tool to discriminate between sterile and wild Q-flies in SIT programs, regardless of the composition of the larval or adult pre-release diets.

The full paper was published in: Journal of Pest Science (2021), https://doi.org/10.1007/s10340-021-01383-2

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.

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 00:1–10.

DEMIRBAS-UZEL, G., A.A. AUGUSTINOS, A.G. PARKER, K. BOURTZIS, A.M.M. ABD-ALLA et al. (2021). Interactions between tsetse endosymbionts and *Glossina pallidipes* salivary gland hypertrophy virus in *Glossina* hosts. Frontiers in Microbiology. 12:653880.

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. Sci Rep 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 6:3, 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. MENÉNDEZ, E. PRIETO, R. ARGILÉS, 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.

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. BIMBILÉ 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.

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.

RAMÍREZ-SANTOS, E., P. RENDON, G. GOUVI, K. BOURTZIS, C. CÁCERES 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., 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.

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.

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.

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.

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 p. 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 p. 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 the improvement 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. BIMBILÉ 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. BIMBILÉ 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. SASSÙ, 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.

VILJOEN, G.J., R. PEREIRA, M.J.B. VREYSEN, G. CATTOLI, M. GARCIA PODESTA (2020). Agriculture: Improving Livestock Production, Reference Module in Earth Systems and Environmental Sciences, Elsevier.

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 NTD 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.

BIMBILÉ 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. CÁCERES, 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-BARRIOS 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.

SASSÙ, F., K. NIKOLOULI, R. PEREIRA, M.J.B. VREYSEN, C. CÁCERES 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). 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.

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). E-learning Course on Fruit Fly Trapping in Support of Sterile Insect Technique Implementation. https://elearning.iaea.org/m2/course/index.php?categoryid=50.

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.), Vienna, Austria. 17 pp. http://www-naweb.iaea.org/nafa/ipc/public/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. http://www-naweb.iaea.org/nafa/ipc/public/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. http://www-naweb.iaea.org/nafa/ipc/public/Guia210220.pdf.

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 http://www-naweb.iaea.org/nafa/ipc/public/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. http://www-naweb.iaea.org/nafa/ipc/public/Guidelines-for-MRR-Aedes_v1.0.pdf.

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.

For further queries, please contact Svetlana Piedra Cordero (S.Piedra-Cordero@iaea.org), Elena Zdravevska (E.Zdravevska@iaea.org), or the Insect Pest Control Subprogramme, Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture, IAEA (http://www-naweb.iaea.org/nafa/ipc/index.html).

Impressum

Insect Pest Control Newsletter No. 97

The Insect Pest Control Newsletter is prepared twice per year by the Insect Pest Control Section, Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture and FAO/IAEA Agriculture and Biotechnology Laboratories, Seibersdorf

International Atomic Energy Agency
Vienna International Centre, PO Box 100, 1400 Vienna, Austria
Printed by the IAEA in Austria, July 2021

21-01678