

4th TEAM meeting 5-9 October 2020

Tephritid Workers of Europe, Africa and the Middle East

BOOK OF ABSTRACTS



La Grande-Motte SOUTH OF FRANCE

www.alphavisa.com/team/2020







WELCOME

Dear Colleagues,

The TEAM meeting is approaching. As you know, due to the special circumstances, we decided to change the format and make it a combined physical and virtual meeting.

Thus far, around 200 participants have registered for the webinar and about 20 people will be physically present in La Grande-Motte. Thanks to this virtual format, we can already anticipate a large participation, which is a great satisfaction considering the context.

The program of presentations is now finalized and can be consulted on the website. Most e-posters have been sent and we thank all the contributors for adapting the format of their work to better fit a screen. On Friday, October 9th, we will award prizes for best oral presentation and best poster, with a student category.

The evolution of the health situation in France forces us to adapt constantly. We will take the greatest care to respect the regulatory sanitary measures and to protect the participants present. The technical visit has yet to be finalized. We do not know yet if it will be possible to organize it. Please excuse us for this.

We truly hope that this meeting will be a success in spite of the sanitary context and will allow interesting scientific exchanges among participants.

We are looking forward to seeing you on screen or in La Grande-Motte.

With best regards, on behalf of the Local Organising Committee,

Valérie Balmès Chairperson: Organising Committee, TEAM 2020 Marc De Meyer Chairperson: Scientific Committee, TEAM 2020



Organisers







ACKNOWLEDGMENT

The Organisers would like to thank public partners for their support of the 4th TEAM meeting.

















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	Monday October 5 th		Tuesday October 6 th		Vednesday October 7 th		Thursday October 8 th		Friday October 9 th
08:30	Registration	·							
00:01	Behaviour and Physiology Open		Taxonomy and phylogeny SIT: Sterile Insect Technique IPM: Integrated Pest Management		Invasion and Ecology Traps and attractants		Biogeography, distribution and abundance Biological and conventionnal control		Chemosensory perception and reproduction
00:01	Introduction	00:01	Plenary 1	00:01	Plenary 2	10:20	P21	0:20	P31
10.40		10.40		10.40	- 6	10.40	P22	0.40	P32
0.10	PO1		P09	1	P17	0.10	P23		P33
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	Coffee break - e-Posters		Coffee break - e-Posters		Coffee break - e-Posters		Coffee break - e-Posters	07:1	
11:40	P03	11:40	P11	11:40	P19	11:40	P25		Award Prizes
00:21	P04	00.21	P12	00:21	P20	12:00	P26	00:2	
02:21	Closing	07:21	Closing	- 02:21	Closing		Closing	00.0	rinal Gosing
06:21	Lunch Poffao - o Doctore	2.2	Lunch Cofficio - o Doctorio	002	Lunch Poffoo - o Doctore	00:2	Lunch	0027	Lunch box
14:00	CIBICO - 6-LOSIEIS	14:00		13:30		14:00	Ę	4:00	
14:20	P05	14:20	P13		Bus departure	14:20	724		
14:40	P06	14:40	P14			14:40	P28		
1 1 1	P07		P15		Technical tour	1 2 0 0	P29		
	P08		P16		'Institut Français de la Vigne	10.00	P30		
	Closing		Closing		et du Vin'		Closing		
16:00		16:00			and 'Salin d'Aioues-Mortes'	05:01			
	e-Posters selection		Satellite meeting FF-IPM				Free time		Méditerranée room (Level 3)
19:00		19:00		19:00					
19:30	Dinner On the spot			19:30	Dinner in 'La Grande-Motte'	19:30	Closing dinner <i>in</i> 'Yacht Club - La Grande-Motte'		

5-9 October 2020 La Grande-Motte, France Book of abstracts

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	MONDAY 5 OCTOBER
Behavio	ur and Physiology / Open
	Chairs: Francesca Scolari, Patricia Gibert and Gaelle Ramiaranjatovo
10:00-10:40	Introduction Méditerranée room (Level 3) • Marc De Meyer (Belgium) • Marc De Meyer (Belgium)
10:40-11:00	P01 • Group behavior in Drosophila suzukii: a research avenue for population management Alexandra Auguste (France)
11:00-11:20	P02 Biological warfarebetween Drosophila species hints for sustainable crop protection - Simon Fellous (France)
11:20-11:40	Coffee break - e-Posters
11:40-12:00	P03 • The Microbiome and Tephritid Behavior - Boaz Yuval (Israel)
12:00-12:20	P04 • Interspecific interactions between a new invasive Tephritid fruit fly, Bactrocera dorsalis, and other resident species in an insular context - Laura Moquet (France)
12:20-12:30	Closing
12:30:14:00	Lunch - Coffee & e-Posters
14:00-14:20	P05 Méditerranée room (Level 3) Role of developmental plasticity in tethered flight performance of the oriental fruit fly (Hendel) Thabang Moropa (South Africa)
14:20-14:40	P06 • Interspecific competition among three fruit fly species infesting watermelon and zucchini (Cucurbitaceae) Akomavo Fabrice Gbenonsi (Ghana)
14:40-15:00	 P07 Incidence of Wolbachia in tephritid fruit flies from the South African highveld and lowveld against a backdrop of fruit fly diversity - Onkgopotse Seabi (South Africa)
15:00-15:20	 P08 Perception of fruit farmers on the occurrence of <i>Bactrocera dorsalis</i> (Diptera: Tephritidae) and its associated economic impact in Manica province, Mozambique - Laura Canhanga (Mozambique)
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16:00-19:00	e-Posters selection
19:30	Dinner on the spot

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	 Pilot aerial releases of sterile Queensland fruit flies in Australia: Developments and lessons Polychronis Rempoulakis (Australia)
11:00-11:20	P10
	 Fruit Fly Risk Manage an Euphresco Project for better knowledge for better risk management of Ceratitis capitata Wiedemann (Diptera: Tephritidae) - David Lopes (Portugal)
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14:00-14:20	P13 Méditerranée room (Level 3)
	 Development of a system for locating hot spots of Mediterranean flies in apple orchards for more accurate pest control - Amber Hill (Israel)
14:20-14:40	P14
	• Automation of Pest Monitoring - examples from Drosophila suzukii - Johannes Fahrentrapp (Switzerland)
14:40-15:00	P15
	• Symbionts facilitators of insect invasion: a review on Tephritid fruit flies - Abir Hafsi (France)
15:00-15:20	P16
	• Fruit fly invasion in La Réunion - Hélène Delatte (Madagascar)
15:20-15:30	Closing
16:00-19:00	Satellite meeting FF-IPM
	 Fruit fly invasion on the spot: in-silico boosted prevention, interception, detection and off-season management of new and emerging fruit flies in Europe - Nikolaos Papadopoulos (Greece)

Dinner free

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12:20-12:30	Closing
12:30-13:30	Lunch - Coffee & e-Posters
13:30-19:00	Technical tour Bus departure from 'Palais des Congrès' at 13:3
	• 'Institut Français de la Vigne et du Vin'
	• 'Salin d'Aigues-Mortes'
19:30	Dinner in 'La Grande-Motte'

THURSDAY 8 OCTOBER

Méditerranée room (Level 3, station pattern of Bactrocera dorsalis (Diptera: tephritidae) in a mango orchard in sbique - Luis Bota (Mozambique) rol of Drosophila suzukii in cherry with the potential dead-end host Prunus padus? rckoorde (Belgium) e-Posters Pyracantha coccinea), a dead-end trap plant for the biological control of the spotted-wing osophila suzukii) - Romain Ulmer (France) onitoring of genetic diversity and Wolbachia infection of recovered Psyttalia lounsburyi, ent of the olive fruit fly in California - Mélanie Tannieres (France) stesting Tephritidae fruit fly guild and parasitism by Psyttalia phaeostigma : braconidae) - Babatoundé Ferdinand Rodolphe Layodé (Benin) achasmimorpha longicaudata and Fopius arisanus (Hymenoptera: braconidae) in smallholder complexity and connectivity - Shepard Ndlela (Kenya)
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South Africa - Gulu Bekker (South Africa)
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ic patterns and molecular connectivity in the Mediterranean fruit fly <i>Ceratitis capitata</i> Jencing - Maria Belen Arias (UK)
iation and diet effects on the microbiome diversity of three tephritid species, Ita, Anastrepha fraterculus & Anastrepha striata - Katherine Hartle-Mougiou (UK)
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lavarro Llopis. Andrea Taddei and Clelia Oliva

FRIDAY 9 OCTOBER

Invasion and Ecology / Traps and attractants	
	Chairs: Antonis Augustinos and Vincent Jacob
10:00-10:20	P31 Méditerranée room (Level 3)
	 The compounds emitted by host-fruits of tephritid species correlate with fruits phylogeny Gaëlle Ramiaranjatovo (France)
10:20-10:40	P32
	 Using evolutionary clues to infer the ecological importance of semio-chemicals in tephritid-host fruit interactions Vincent Jacob (France)
10:40-11:00	P33
	 Olfactory preference of Drosophila suzukii shifts between fruit and fermentation cues over the season: effects of physiological status Rik Clymans (Belgium)
11:00-11:20	P34
	 Prey can detect predator through chemical cues modifying their oviposition: oviposition avoidance of flies towards Dufour&poison gland chemicals from weaver ant Emilie Deletre (Kenya)
11:20-12:00	Award Prizes
	 Best oral presentation and best poster, with a student category
12:00-12:30	Closing
12:30-14:00	Lunch box



ABSTRACTS MONDAY 5 OCTOBER

Behaviour and Physiology / Open



Group behavior in *Drosophila suzukii*: a research avenue for population management

<u>Alexandra Auguste</u>¹ (alexandra.auguste@inrae.fr), Ludovic Chaumaz¹, Emmanuel Desouhant², Laurence Mouton², Nicolas Ris¹, Xavier Fauvergue¹

¹ ISA, INRAE,Université Nice Côte d'Azur, CNRS, Sophia-Antipolis, France ² Laboratoire de Biométrie et Biologie Evolutive, Université Lyon 1, CNRS, Villeurbanne, France

CrashPest is a four-year project (2020-2023) on the population dynamics of *Drosophila suzukii*. The general question is whether reproductive barriers can be manipulated to decrease pest abundance and possibly, trigger local extinctions. This project has some analogy with the development of mating disruption and Sterile Insect Techniques (SIT), with the difference that our focus is on *Wolbachia*-induced mating incompatibilities. In this context, some research concerns collective behaviors: appropriately combined with incompatibilities, the disruption of such behaviors could contribute to a cascade of population destabilization. We here report findings on social information and aggregation behavior in *D. suzukii*. *Via* a factorial experiment with varying levels of male and female density, we showed that males aggregate on reproduction sites, and that female success to find these sites increases with increasing number of males. This suggest that in *D. suzukii*, breeding dispersal relies on intersexual signals, and that reproductive success is positively dependent (*i.e.* an Allee effect). We discuss these results in the light of the population management of *D. suzukii* and other pest insects.

Keywords: Cytoplasmic Incompatibility - Wolbachia - Aggregation - Allee Effect - Social information.

References:

1. Blackwood J.C. et al. (2018) Journal of Animal Ecology 87, 59-72.

Biological warfarebetween Drosophila species hints for sustainable crop protection

<u>Simon Fellous</u>¹ (simon.fellous@inrae.fr), Antoine Rombaut², Romain Gallet², Kenza Qitout², Mukherjy Samy², Robin Ghuilhot², Pauline Ghirardini², Paul G. Becher³, Anne Xuéreb², Patricia Gibert⁴

¹ CBGP, INRAE, Montferrier, France

² INRAE, Montpellier, France

³ Swedish University of Agricultural Sciences, Alnarp, Sweden

⁴ CNRS, Lyon, France

Species that share the same ecological niche often avoid costly competition with context-dependent behaviors. This is the case of the invasive insect pest *Drosophila suzukii* that can develop in ripe fruit where it encounters *Drosophila melanogaster*. Previous research showed that *D. suzukii* prevents costly larval competition by not ovipositing in substrates with *D. melanogaster* eggs. We discovered *D. suzukii* females respond to cues produced by bacteria in the gut microbiome of *D. melanogaster*. This behavior of *D. suzukii* varied over time and among populations, revealing subtle condition-dependence. In particular, *D. suzukii* females that bore *D. melanogaster* bacteria stopped avoiding sites with *D. melanogaster* cues. The adaptive significance of this behavior was investigated by reproducing experimentally in-fruit larval competition. *D. suzukii* larvae only suffered from competition with *D. melanogaster* if the competitor was associated to its microbiota, suggesting *D. suzukii* has evolved a solution to avoid offspring developing in challenging environments. We argue that *D. suzukii* competition avoidance behavior has features enabling the design of an evolution-proof repellent to protect crops.

Keywords: Drosophila - Repellent - Microbiota - Behavior.

The microbiome and Tephritid behavior

Boaz Yuval (boaz.yuval@mail.huji.ac.il)

Entomology, Hebrew University of Jerusalem, Rehovot, Israel

Multicellular organisms maintain intimate relationships with diverse communities of micro-organisms. These interactions have been studied in depth in many insect species, revealing significant and intricate effects of the microbiome on its host. Most famous are nutritional effects, whereby a primary symbiont provides the host with vital nutrients, such as amino acids or vitamins. In addition, we are aware of systems where the symbionts affect host reproduction, immune response, niche breadth, and environmental resilience. In my talk, focusing on tephritid fruit flies, I will examine the effects of gut symbionts on host behavior.

Keywords: Symbiosis - Medfly - Olivefly - Behavior - Oriental fruit fly.

- 1. Yuval, B. (2017). Current Biology 27, R746-R747.
- 2. Akami, M. et al. (2019). PLoS One 14, e0210109.
- 3. Jose, P.A. et al., (2019). Journal of insect physiology 117, 103917.

Interspecific interactions between a new invasive Tephritid fruit fly, *Bactrocera dorsalis*, and other resident species in an insular context

Laura Moquet¹ (laura.moquet@cirad.fr), Benoît Jobart¹, Hélène Delatte²

¹ PVBMT, CIRAD, Saint Pierre, Réunion, France ² CIRAD, Ambatobe, Madagascar

Biological invasions of insects considered as pests have important negative impacts on the economy and the environment, partly because invaders can affect the structure of the community through direct and indirect effects on resident species.

Since the detection, in April 2017, of one of the most harmful pests of fruit and vegetable crops worldwide, *Bactrocera dorsalis*, Reunion island counts nowadays nine pests species of Tephritid fruit fly pest species of economic importance. Despite the presence of a biological control agent, *Fopius arisanus (Braconidae)* originally introduced for controlling *Bactrocera zonata*, *B. dorsalis* was found to have a high infestation rate and an extreme polyphagy. Since its invasion, the structure of the fruit fly community has changed: the most abundant species on the island, *B. zonata*, has almost disappeared, and the host range of other polyphagous species (*C. capitata and C. quilicii*) has been modified.

To understand the invasion process of *B. dorsalis* and the impact of this newly introduced fruit fly on the community structure of the resident Tephritid species, and the parasitoid *F. arisanus*, it is necessary to study interactions experimentally. We assessed both direct and indirect interactions among polyphagous fruit flies and *F. arisanus*: i) by analysing interspecific competition among fruit flies, considering competition among female adults for oviposition and competition among larvae for food resources; ii) by observing host species preference of *F. arisanus* according to plant species; and iii) by testing the effects of indirect interactions among fruit fly species mediated by *F. arisanus*.

Keywords: Biological Invasion - Fopius arisanus - Competition - Indirect Interactions.

Role of developmental plasticity in tethered flight performance of the oriental fruit fly (Hendel)

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² Department of Behavioral and Chemical Ecology, International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya

During the past decade, the oriental fruit fly, *Bactrocera dorsalis* (Hendel), has invaded and become established in the northern regions of South Africa¹. It has expanded from its native range due to its adaptability to various climates, human-assisted dispersal, as well as its high capacity for dispersal by flight². Nutrition can affect flight capacity in insects by causing changes in morphology³. In *B. dorsalis*, changes in wing shape result from development in different host fruit, but the functional implications of these changes are not known. We investigated the effect of development in different host fruit (mango, guava, papaya, grapefruit and orange) on flight capacity of *B. dorsalis* by recording tethered flight for six hours using computerised flight mills. Proportional larval and pupal survival were lowest from oranges and grapefruit, respectively. Larval and pupal development was slowest in oranges. Flight propensity differed among the fruit types, with flies reared on mango least likely to fly. Females were more likely to fly than males. A maximum flight distance of only 73.05 metres was recorded, but average flight distance was affected by fruit type, with flies reared from grapefruit covering the shortest distance. There was no significant effect of sex on flight duration. These results show that flight by *B. dorsalis* is affected by developmental host and are in accordance with other studies showing that citrus is a poor host for this species.

Keywords: Dispersal Ability - Flight Mill - Oriental Fruit Fly - Wind Loading - Wing Shape.

- 1. Grout, T. & Moore, S. (2015). Insects of cultivated plants and natural pastures in Southern Africa, 447-501.
- 2. Chen, M. et al. (2015). Journal of Insect Science, 15.
- 3. Pieterse, W. et al. (2017). Zoologischer Anzeiger 269, 110-116.

Interspecific competition among three fruit fly species infesting watermelon and zucchini (Cucurbitaceae)

<u>Akomavo Fabrice Gbenonsi^{1, 2}</u> (fagbenonsi@st.ug.edu.gh), Sahadatou Mama Sambo², Babatounde Ferdinand Rodolphe Layode², Abègnonhou Félicien Totin², Alexis Onzo¹, Miriam Frida Karlsson^{2, 3}

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Interspecific competition occurs among arthropod pest species that share hosts, thereby, influencing their population dynamics. In sub-Saharan Africa, the native fruit fly species Dacus vertebratus (Bezzi) and Dacus ciliatus (Loew) (Diptera: Tephritidae) and the exotic Zeugodacus cucurbitae (Coquillett), are concurrent pests in the same host fruits, hence competition among them is likely to occur. We explored interspecific competition among these three fruit fly species on Cucurbita pepo L. and Citrullus lanatus Thunb (Cucurbitaceae) to improve our understanding of the interaction between the species and their capacity to coexist. We exposed the vegetable fruits to different densities of fruit fly species and studied their behavioural activities, evaluating the extrinsic competition. To assess intrinsic competition and understand the effect of co-occurrence inside the fruits, eggs of the three fruit flies were pairwise inoculated into the same fruits. Results showed that the behaviour on the fruits differed between the species and that the interspecific competition affected their developmental time and larval survival in both watermelon and zucchini. Z. cucurbitae were more aggressive than the other species and managed to oviposit more frequently. Emergence was reduced for D. ciliatus and D. vertebratus when inoculated together with Z. cucurbitae in watermelon but not in zucchini. Physical confrontations were more common in zucchini than in watermelon and were more frequently won by Z. cucurbitae than D. vertebratus and D. ciliatus. Interspecific competition information obtained on behavioural differences and interaction effects, provides background for explaining the present fruit fly guild on certain Cucurbitaceae fruits in West Africa.

Keywords: Tephritidae - Behavioural Activities - Zeugodacus cucurbitae - Dacus vertebratus - Dacus ciliatus.

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Incidence of *Wolbachia* in tephritid fruit flies from the South African highveld and lowveld against a backdrop of fruit fly diversity

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Tephritid fruit fly pests are of consistent international concern due to the damage caused to fruit and vegetables¹. Owing to this, research is being conducted to understand interactions between fruit flies and bacterial symbionts for biocontrol purposes. Wolbachia is one such bacterial endosymbiont, which could be exploited as a genetic control measure through cytoplasmic incompatibility². We determined the incidence of Wolbachia in tephritid populations in the South African Highveld and Lowveld. We developed a molecular protocol combining detection of Wolbachia infection with host identification. All 2,989 flies sampled in this study were identified to nine species in three genera using morphological keys, following which a subset of 110 flies were selected for molecular identification using primers targeting the cytochrome c oxidase I (COI) barcode region. As in other studies, molecular identification using COI barcoding was incapable of discriminating between sister taxa, like Ceratitis rosa and Ceratitis quilicii³. To date, Wolbachia presence in sampled fruit flies has been determined through PCR screening of 500 individual flies, followed by nucleotide sequencing. Initially a three-gene multi-locus sequence typing (MLST) approach using primers targeting the 16S rRNA, wsp and ftsZ gene regions was used. However, due to poor performance of the ftsZ assay, an optimised wsp-16S rRNA two-gene screening approach was used instead. Based on the molecular screening results, Wolbachia was detected in a single C. cosyra fly from the Highveld region, corresponding to an overall prevalence of 0.2%. Based on this low *Wolbachia* prevalence, a biocontrol programme may be feasible in South Africa.

Keywords: Wolbachia - Multi-locus Sequence Typing (MLST) - Molecular Identification - Genetic Control - COI Barcoding.

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Perception of fruit farmers on the occurrence of *Bactrocera dorsalis* (Diptera: Tephritidae) and its associated economic impact in Manica province, Mozambique

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Fruit flies (Dipera: Tephritidae) are among the most important pests of fruits and vegetables in the world. The invasive species, *Bactrocera dorsalis* was detected in Niassa province in 2007, and in 2008 it was present in Manica province, causing damage on fruits and commercial restrictions. Therefore, there was a need to implement a program for B. dorsalis management. However, there was no baseline information regarding key features associated with the knowledge, perceptions, impact and practices of fruit producers regarding fruit fly pests and their management. In February 2015, fruit farmers from different districts of Manica province were interviewed. Frequencies and analysis of variance were performed through SPSS 16.0 and STATA 12.0. Were interviewed 36 fruit farmers from six districts covering 352 ha (46.72%, 34.02% and 10.32% with mango, banana and citrus, respectively). Fruit flies were the main pest in 80% of mango and citrus orchards and in 19.0% of the banana plantations. 58.33% of the farmers could not identify fruit flies species although they could describe symptoms of damage (91.66%). 70% the respondents indicated increasing volumes of uncommercialized fruits, since the detection of the pest. The loss monetary value was severe for mango, reaching USD 135,784.8 in 2014/15 crop season. The small scale mango farmers do not control the pest mainly because they were not aware of the fruit flies management strategies. Training on pest identification and management strategies should be conducted among small scale farmers in Manica province to reduce the economic loss caused by fruit flies.

Keywords: >Farmer's awareness - Monetary losses - Uncommercialized fruits - Fruit fly management practices.

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ABSTRACTS TUESDAY 6 OCTOBER

Taxonomy and phylogeny / SIT: Sterile Insect Technique IPM: Integrated Pest Management



Plenary 1

Demystifying the tools: New approaches for insect taxonomy and phylogeny

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Pilot aerial releases of sterile Queensland fruit flies in Australia: Developments and lessons

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The Sterile Insect Technique (SIT) has been tested as a control method against the Queensland fruit fly *Bactrocera tryoni* over the last 50 years. Previous studies were conducted with ground releases of pupae or young adults with varying results. Lately a substantial body of knowledge has been accumulated, mostly through the research activities of the SITPlus consortium. Recent developments in colony management, larval and adult nutrition, prerelease treatments and release methods provide new prospects for efficient and successful implementation of SIT for control or local eradication of this important pest.

Here we present the first results of a large-scale aerial pilot release experiment that took place during September 2019 - May 2020 in Hillston, NSW. 2 million sterile flies per week were sourced from South Australia and shipped to a rear out facility in Yanco, NSW. Upon emergence flies were fed with yeast hydrolysate and sugar for 5 days, then chilled and loaded into a release apparatus and air transported to the study area (Hillston town and adjacent commercial farms) where they were released. A network of Lynfield traps with cue lure as attractant was inspected weekly for wild and sterile flies, and a similar sized area 100 Km away was used as control.

We recorded a significant proportion of recaptured sterile males, especially close to drop zones, indicating good quality, survival and dispersal in the field. Here we discuss the findings and the significance of maintaining insect quality and proper operational procedures for the success of this control methodology.

Keywords: Q-fly - Tephritidae - SIT - Quality - AW-IPM.

Fruit Fly Risk Manage an Euphresco Project for better knowledge for better risk management of *Ceratitis Capitata* Wiedemann (Diptera: Tephritidae)

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Ceratitis capitata (Wiedemann), also known as Mediterranean fruit fly, is one of the world's most destructive plant pests. It is a highly polyphagous species able to feed on over 300 hosts, and it is known to be capable of adapting to a wide range of climates. This pest has spread to the EPPO region, it is mainly present in the southern part, where it is particularly damaging for *Citrus* and *Prunus*; records in Northern or Central Europe refer to interceptions or short-lived adventive populations only. Sustainable programs for surveillance, dispersion assessment of its spread and the implementation of control measures for control of pests of great economic importance such as C. capitata represents the main challenge that every country must face. Comprehensive information on C. capitata occurrence, both in spatial and temporal terms, in the partner's countries was crucial for understanding the current and historical extent of its occurrence, conditions of survival and areas susceptible to potential invasion and establishment in each of the partner's countries studied. The key outputs and results included the analysis and brief biological characterization of populations occurring worldwide, a review of early detection tools and management strategies used in different countries, testing of new methods for monitoring and early detection, and the build and dissemination of models for pest emergence and risk maps of C. capitata in different climatic regions as an important tool to concentrate the actions in the different countries. The project research Consortium includes fifteen institutions.

Keywords: Fruit fly - Risk maps - Models - Biological characterization - Pest management..

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A systems approach for mitigation of fruit fly risk in citrus produced in South Africa

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A systems approach is being used to mitigate risk of fruit fly infestation in citrus produced in South Africa and exported to the European Union. The systems approach consists of independent fruit fly control measures before and after harvest, which cumulatively reduce the risk of fruit flies in citrus from South Africa. Fruit fly good agricultural practices, which include monitoring and control using attract and kill methods, are used to reduce risk of infestation in citrus orchards. Attract and kill methods, which are registered for fruit fly control in citrus orchards in South Africa, were found to be successful in largely preventing fruit infestation in commercial citrus. Ceratitis capitata (Wiedemann) was the only species reared out of the few damaged citrus fruit occasionally recorded in orchards treated with registered products. Grading and inspections at the packhouses are measures applied after harvest to further reduce risk of fruit flies in citrus fruit. For citrus other than lemon and limes, cold shipping conditions are the final step in achieving quarantine security for fruit fly pests. Among the fruit fly pests of citrus in South Africa, C. capitata was found to be the most cold-tolerant. The effect of shipping conditions on survival of residual fruit fly infestations can therefore be calculated using readily available C. capitata cold treatment dose response data. In conclusion, a systems approach consisting of pre-harvest and post-harvest control measures is being used as an effective way of mitigating the risk of fruit flies in export citrus from South Africa.

Keywords: Control - Pre-harvest - Post-harvest.

Impact of regionally managed collective action in Medfly AW-IPM

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Israel has switched to a regional IPM of Medfly (*Ceratitis capitata*) in deciduous orchards, covering more than 70% of the country's orchards in the three main growing areas, and led by the ministry of agriculture and regional organizations. Unlike common SIT based area wide IPM projects, these projects are based on mass trapping with minor GF-120 spraying when necessary, demanding a high level of bottom-up collaboration between growers who practically apply a substantial part of required actions (timely mass trapping placement, sanitation, ground spraying etc.). Management strategy is based on a spatial view of the entire region in terms of crops, other existing plant protection issues and social nature of the villages, providing a specific real time and local advice when Medfly problems arise.

The impact was examined using indices of fruit infestation and damage, reduction in spraying rounds' number, Conversion from use of Organo-Phosphates to low toxicity materials (using EIQ index), and monitoring of pesticide residues in the fruits.

Large scale regional IPM in collaboration with many growers made it possible to study the hotspot phenomenon, understand the impact of surrounding natural vegetation on Medfly population and behavior and the beneficial impact of full sanitation on reducing fly populations.

Regional management allowed also upgrading of pest scouts' work and formulation of common and effective IPM scouting standards; it also contributed to strengthening of environmental-agricultural interface (agroecology), and promoted a regional and holistic standard of agricultural culture among growers.

Keywords: MedFly - Ceratitis Capitata - AW-IPM - Agro-ecology.

Development of a system for locating hot spots of Mediterranean flies in apple orchards for more accurate pest control

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The Mediterranean fruit fly (Medfly), Ceratitiscapitata (Wiedemann) (Diptera: Tephritidae), is a major pest causing large economic burden and fruit damage to crops worldwide, especially in the Mediterranean area. In deciduous orchards, monitoring the population of Mediterranean fly is an intensive and expensive process. Along with this, the use of phosphates pesticides was banned due to the damage to the plants and surrounding habitats. In order to optimize the time and effort-consuming practice of Medfly field monitoring, and to promote more site-specific pesticide applications, there is a need for more accurate within-orchard trap placement by accounting for the heterogeneous spatial distribution patterns of Medflies within the orchard. Medfly population increases in certain small locations often precedes the infestations in surrounding orchards. In the current work we identified the differences between these locations (termed 'hot spots') and locations representing the rest of the orchard (termed 'cold spots'). We examined differences in fruits volatiles and spectral signature profiles of the fruits, temperature, humidity and leaf area index. The results showed that hots spots were characterized by higher leaf area index, lower temperatures and higher humidity compared to the cold spots. In addition, the fruits in the hot spots had higher nitrogen levels, different volatile profile and different spectral signature. These differences can help in identifying hot spots in other orchards and provide an important tool for effective prediction and control of pest emergence.

Keywords: Medfly - Hot spot - Volatile - Nitrogen levels - Spectral signature.

Automation of Pest Monitoring – examples from Drosophila suzukii

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Spotted Wing Drosophila SWD (Drosophila suzukii) has become a serious pest in Europe attacking soft-skinned crops such as several berry species and grapevine. An efficient and accurate monitoring system to identify the presence of SWD in crops and their surroundings is essential for the prevention of damage to economically valuable fruit crops. Existing methods for monitoring SWD are costly, time and labor intensive, prone to errors, and typically conducted at a low spatial resolution. To overcome these limitations, we are developing a novel system using photographable traps, which are monitored by means of Unmanned Aerial Vehicles (UAVs) and an image processing pipeline that automatically identifies and counts the number of SWD per trap location. To this end, we collected high resolution RGB imagery of SWD caught alternative traps taken from both a static position (tripod) and from a UAV, which were then used as input to train deep learning models. Results show that a large part of the of SWD can be correctly identified by the models. Trap performance and the autonomouse flight of UAV platforms as well as their sensor quality needs further investment and are part of current works. Drones will be programmed to capture imagery of the traps under field conditions. The collected imagery will be transferred directly to cloud-based storage for subsequent processing and analysis to identify the presence and count of SWD in near real time. This data will be used as input to a decision support system (DSS) to provide valuable information for farmers.

Keywords: Pest monitoring - Agriculture - Machine learning.

Symbionts facilitators of insect invasion: a review on Tephritid fruit flies

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Insects harbor a diversity of microbes that can profoundly influence their biology and by extent, their ecology and evolution. Symbionts are reported to affect their host's response toward biotic and abiotic stressors. This can be particularly important in the current context of global climate change and of intense anthropogenic activities, which impose fast and drastic environmental changes to which organisms do not necessarily have the time to adapt. Symbionts often accompany alien species and can influence the host at various stages of invasion playing a major role in the success or failure of insect invasions. Despite that the invasive species often depend on microbial symbionts, few studies have examined the evolutionary dynamics and the role of symbionts during the different invasion stages. Focusing on the highly successful invasive pest family, Tephritidae, we aim to integrate issues related to the role played by their symbionts in those different invasion processes. First, we looked at prevalence and diversity of symbionts species that facilitate the colonization of new habitats. Next, we describe how symbionts can influence the development and the fitness of their hosts during their establishment by enhancing r-selected traits. Finally, we expose through examples, the role of tephritid-symbiont associations in the adaptation to biotic and abiotic stress that allow dispersal and expansion of invasive species in the recipient ecosystem. Given the importance of symbionts in determining the insect invasion, it will be interesting to consider them in pest risk analyses, spread and impact modeling, to optimize the management of invasive pests.

Keywords: Abiotic-biotic stressors - Invasion - Gut symbiont - Tephritidae - Wolbachia.

Fruit fly invasion in La Réunion

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The establishment and spread of non-native insects in new regions, are a component of global change, and their impact on the resident invaded communities and ecosystems has economic and environmental consequences. Here we propose to follow the spread of a top invader species of the Tephritidae family in an insular environment regarding to its influence on the resident community. Bactrocera dorsalis, a fruit fly of Asian origin, is an extremely polyphagous species known as one of the top invader in the world, threatening agriculture. It has spread rapidly throughout Africa, since 2003, and has further invaded all countries of sub-Saharan Africa as far as the Indian Ocean Islands of the Malagasy sub-region. The latest detection was in 2017 in La Réunion. In this island, the resident tephritid community had already eight species, resulting for most of them of past invasion events. Before the arrival of *B* dorsalis these species were considered as a stable community. In less than two years, the most abundant species on the island, B. zonata, has almost disappeared; B. dorsalis spread in all different niches of the island up to 1400 m; it was found in over 50 hosts, revealing its extreme polyphagia compared to the resident community. It attacked previously non-host, or low occurrence-hosts, including endemic fruits never recorded as tephritid host, demonstrating its ability to adapt and quickly establish in new environments. Understanding both impacts and ecological processes that promote invasion is a first step to prevent future invasions and to manage existing ones.

Keywords: Niche partitioning - Top invader - Competitive displacement - Host shift.

FF-IPM

Fruit fly invasion on the spot: in-silico boosted prevention, interception, detection and off-season management of new and emerging fruit flies in Europe

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The risks of arrival, establishment and range expansion of *Ceratitis capitata*, Bactrocera dorsalis, and B. zonata, which are major invasive fruit flies of global concern, are expected to escalate because of global climate change, increased trade and human mobility. In addition, the ban of neonicotinoids, which is one of the main control tools against fruit flies in Europe, poses an additional burden on fruit growers in Europe. To address the European needs (small size, scattered farms, operated under diverse socioeconomic and regulatory frameworks), the Horizon 2020 funded project FF-IPM (number 818184) builds on existing knowledge, identifies and fills the critical information gaps, boost regional fruit fly prevention by developing new and enhancing the existing interception and detection tools to provide new in silico assisted Integrated Pest Management approaches that will be validated and adapted to European socioeconomic and agricultural conditions. The FF-IPM response toolbox against emerging (C. capitata) and new (B. dorsalis, B. zonata) fruit fly pest is reinforced by a set of novel decision support tools, dedicated and optimized to each of the target species. This is accomplished by a strong group of 21 partners from academia (8), research institutes and museums (5), businesses (5) and growers' organizations (3). FF-IPM follows a multiactor approach, with genuine coordinated involvement of relevant actors/stakeholders, and substantive roles envisaged for them and in-built into its Work Plan.

Keywords: Invasion biology - Fruit flies - Tephritidae - Integrated Pest Management - Detection, incursion, interception.



ABSTRACTS WEDNESDAY 7 OCTOBER

Invasion and Ecology / Traps and attractants



Plenary 2

Drosophila suzukii: The reasons of its success

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Drosophila suzukii is a species with the dual characteristic of being both an invasive species and a crop pest. This species, which was virtually unknown about ten years ago, has therefore been the subject of numerous studies in both fundamental and applied research. Twelve years after its first detection in Europe and North America, what have we learned about the ecology of this species? Does this knowledge make it possible to envisage new strategies for the control of this pest? I will present the results on the ecology of this species obtained in recent years.

Identification of olive tree kairomones attractant to *Bactrocera oleae* for mass trapping

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By laying its eggs in unripe and ripening olive fruits, the olive fly, *Bactrocerao oleae* significantly decreases the production of olive oil and table olives worldwide – between 5 to 30% loss – and consequently has a major economic impact. Today, male attractant pheromone traps are used to monitor olive fly populations and ammonium-based traps are used to control them but with no real specificity and success. The objective of this study was to identify olive tree kairomones attractant to olive fly females for mass trapping. Using GC-MS analyses, the volatiles of one attractive and two non-attractive olive trees varieties were identified and compared. The attractiveness of ten individual volatile compounds were evaluated in a Y-tube olfactometer. Finally, two kairomones were tested at two concentrations in the field in combination or not with the pheromone and compared with ammonium-based traps. Five traps were set up per modality in four sites and lures were changed every four weeks. We observed a synergetic effect of pheromone and kairomones on the number of flies caught.

Keywords: Attractant - Fruit flies - Pheromones - volatiles.

Tunnel entries and a killing agent uncover the importance of fly retention in Drosophila suzukii traps

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Spotted wing drosophila (SWD), *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae), is a pest of stone and small fruits causing considerable economic losses. Current management strategies primarily rely on calendar-based spraying, due to the poor relationship between monitoring data and damage levels and the lack of success of mass trapping tools. The aim of this study was to evaluate different trap models for SWD, with an emphasis on their fly retention capacity. To this end, we examined and quantified the added value of two fly retaining trap features; tunnel entries to impede escaping and an insecticide-coated inner surface as a killing agent. An insecticide-coated inner surface resulted in a significantly higher trap retention after 24 hours in the laboratory (4.9- to 7.4-fold greater, depending on trap type) compared to a non-coated trap. Trapping efficacy was significantly improved in field trials by such a killing agent in the trap (1.2- to 4.5-fold greater). Also tunnel entries significantly improved trap retention in the laboratory and field (by 1.5-fold).

The outcomes of this study clearly reveal the substantial impact of the fly retention capacity of SWD traps on their overall capture performances. It was demonstrated for the first time that an insecticide-coated inner surface as a killing agent significantly improves trap efficacy for SWD. This finding can readily be implemented in any trap model to improve monitoring and mass trapping of SWD. Also tunnel entries were shown to have a significant influence on the fly retention and hence substantially enhance trapping efficacy.

Keywords: Trap design - Fly retention - Killing agent - Insecticide - Drosophila suzukii.
Remote surveillance of invasive and geographically expanding fruit flies with electronic traps

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Most National Plant Protection Organization (NPPO) around the world keep surveillance systems in sensitive locations to promptly detect exotic, or geographically expanding, pestiferous fruit flies that may threaten their fruit production. These surveillance systems allow the NPPO's, or grower's organizations, to react in case that an exotic fruit fly is detected, reducing the probability of establishment and economic damage. In general, in the best of the cases surveillance systems are serviced on a frequency of once a week by scouts, while most surveillance systems have longer delays in their frequency of service. Most of these surveillance systems are highly demanding in investment of large amount of resources and efforts. In addition, current surveillance systems of exotic fruit flies have an intrinsic "delay" in the detection and reporting of invasive fruit fly species, affecting NPPO's response to the threat. During the last years we have been developing an electronic trap that remotely transmit images of captured fruit flies through cellular communication. The current e-trap prototype is being tested within the framework of the FF-IPM Horizon 2020 project, and is expected to be implemented in future pilot tests in several regions. This talk will present the concept of the e-trap as an «Early-Warning Tool», and current advances in the direction of its future implementation in novel surveillance strategies being designed by the FF-IPM project to increase the efficacy of current surveillance systems.

Keywords: Electronic Trap - Exotic Fruit Flies - Surveillance.

The attractiveness of locally made baits of plant origin for capturing Bactrocera dorsalis and Ceratitis cosyra on mango

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In Nigeria, the majority of mango producers are small holders who may not afford the cost of imported materials for the detection and management of fruit flies. The present work reports on the exploitation of local materials for mango fruit fly management. To produce an oil attractant (CLO) for *Ceratitis cosyra*, cushed leaves and inflorescences of the local clove *Syzygium caryophyllatum* were subjected to distillation process. The extracted oil known to contain eugenol, caryophyllene derivatives (sesquiterpenes) and non-phenolic compounds was subjected to treatments to isolate eugenol further synthesized to a local methyl eugenol (LME) for attracting Bactrocera dorsalis. The attractiveness of (a) CLO and terpinyl acetate (TA) to Ceratitis cosyra and (b) LME and commercial methyl eugenol (ME) to Bactrocera dorsalis were compared in 2 ha mango orchard. Tephri traps separately baited with the test attractants were hung on mango trees separated by 50m intervals. The arrangement was a randomized complete block with 3 replicates. Significantly (P<0.05) higher number of C. cosyra was captured in CLO traps compared to that of TA in 3 months (3.8 as against 1.7 flies/ trap/day). In the same period, there was no significant (P>0.05) difference between the number of B. dorsalis caught in commercial ME traps compared to those of LME (8 flies/trap/day and 5.5 flies/ trap/day respectively). However, CLO attracted negligible number of C. dittisima and C silvestri; while LME attracted Dacus bivittatus and Zeugodacus cucurbitae. In the absence of conventional baits for Bactrocera dorsalis and Ceratitis cosyra, locally produced homologues can be utilized.

Keywords: Bactrocera dorsalis - Ceratitis capitata - Syzygium caryophyllatum - Tephri trap.

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Invasion and Ecolog / Traps and attractants



ABSTRACTS THURSDAY 8 OCTOBER

Biogeography, distribution and abundance Biological and conventionnal control



Geographic variation and diet effects on the microbiome diversity of three tephritid species, *Ceratitis capitata, Anastrepha fraterculus & Anastrepha striata*

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The Tephritidae family has been studied due to their damaging effects on crops. Particular interest has been directed towards the microbiome of tephritids to understand the microbial interactions that influence their biology. In the context of managing pests, microbiome composition may be particularly informative when comparing the differences between native and introduced ranges, while considering fruit fly diet variation. Such ecological parameters can create selective pressures that might be the source of diverse responses to management strategies. The invasion dynamics and worldwide distribution of such species have been widely described; however, the fly microbiome diversity has yet to be explored. This study focused on the microbiome description in tephritid species, the worldwide distributed Ceratitis capitata and the native American species Anastrepha fraterculus and Anastrepha striata, collected from various host plants. C. capitata was collected in six countries (South Africa, Spain, Israel, Australia, Colombia, and Brazil) while Anastrepha spp. were collected in Colombia. The 16S ribosomal region was studied to assess the bacterial community structure. On a global scale, the medfly microbiome presented significant differences according to its diet in the Neotropic. The Brazilian specimens' microbiome was the most distinct compared to the other populations. In Colombia, interspecific variation of the microbiome was associated with the evolutionary origin of the fly species, whereas intraspecific differences were linked to dietary habits at local scale. Different strains of *Wolbachia* were also present. The results may contribute to the understanding of the success of invasions and help in the implementation of pest management programs.

Keywords: Medfly - Anastrepha - microbiome - Wolbachia - South American fruit fly.

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Phylogeographic patterns and molecular connectivity in the mediterranean fruit fly *Ceratitis capitata* using rad-sequencing

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The tephritid fruit flies (Diptera: Tephritidae) are amongst the most successful invaders and most devastating agricultural pests recognised worldwide. The Mediterranean fruit fly Ceratitis capitata, commonly known as medfly, is particularly important because it has a wide range of host plants, however, because of its worldwide distribution, it has also become an attractive model for the study of evolution and adaptation in newly colonised environments. Here, we conducted a genome-scan analysis using a restriction associated DNA-sequencing (RAD-seq) method in C. capitata populations collected from South Africa, Spain, Greece, Guatemala, Brazil and Australia. A total of 1,907 neutral snps from 92 individuals were identified and used to assess the genetic divergence between populations and document their structure and phylogeographic history. Our results revealed a gradual decrease in genetic diversity linked to the geographical dispersal of medfly populations from South Africa (native range) to the rest of the world (introduced range) in accordance with previous studies. Clustering analysis (including DAPC, STRUCTURE and fineRADstructure) identified three genetic clusters corresponding to: South Africa, Brazil and the rest of populations. Sub-structuring the introduced region (Spain, Greece, Guatemala, Brazil, Australia), three genetic clusters were identified, and one was unique for Brazil's population, which might be considered as new evidence in the colonisation process of this species in Latin America. Moreover, adaptive signatures were found across the genome, and most of them associated with intronic regions. Our results contribute to a better understanding of the evolutionary mechanisms underlying medfly invasions.

Keywords: Medfly - Population genetics - Phylogeography - Invasive species - RAD-seq.

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A spatial perspective of fruit fly (Diptera: tephritidae) trap catches within a mixed fruit orchard in the Western Cape, South Africa

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Ceratitis capitata (Wiedemann) (Diptera: Tephritidae) is the most economically important fruit fly in the Western Cape, South Africa, causing fruit damage and posing a phytosanitary risk, followed by the recently described *Ceratitis quilicii* De Meyer, Mwatawala and Virgilio. Understanding the within-orchard spatial and temporal distribution and dynamics of these flies can improve fruit fly management and control. We investigated the spatial distribution and spatial associations between *C. capitata* and *C. quilicii* female trap catches in a heterogeneous orchard environment, making use of weekly adult female trap catch data collected from commercial fruit crops, home gardens, natural vegetation and windbreaks. Females of both species indicated aggregated spatial patterns; however, *C. capitata* significantly aggregated more towards the end of the season while *C. quilicii* females were spatially associated, most prominently in home gardens, natural vegetation, citrus and nectarines. Results suggest dispersal of the two species from unmanaged home gardens and natural vegetation to commercial orchards.This study provides valuable information for decision-making within an integrated pest management strategy.

Keywords: Spatial Analysis - IPM - Distribution - Spatial Association - Ceratitis.

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Distribution and seasonal abundance of three tephritid species of economic importance in Burkina Faso according to the three types of plant formations

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A 2-year mass trapping exercise and fruit sampling and incubation in Western Burkina Faso between May 2017 and May 2019 in natural fallows, agroforestry parks and mango orchards identified three tephritid species of economic importance : Bactrocera dorsalis, Ceratitis cosyra and Ceratitis silvestrii. They are responsible for major damage on two fruit species of major economic importance in Burkina Faso: mango and shea fruits. In mango orchards, B. dorsalis commonly emerged (62.11% of adult flies) from mango, followed by C. cosyra (35.57%). In agroforestry parks, C. silvestrii represented 55.41% of adult flies emerged from shea fruits, following by *B. dorsalis* (40.68%). In natural fallows, *C. cosyra* represented 82.04% of adult emerging from wild host fruits. These three tephritid species accounted for more than 97% of the specimens caught. Bactrocera dorsalis accounted for 70.71% of the catches and its population was very dense during the rainy season with a peak recorded in late june (195.14 FTD) or in mid-July depending of the plant formations. Its peak of abundance coincided with the maturity of mango and shea fruits. Ceratitis cosyra with 18.78% of the catches presented a peak in mid-May (142.04 FTD) corresponding with the presence of early mango varieties, guava and several wild and indigenous hosts. Ceratitis silvestrii represented 7.79% of the adult caught, and showed a 1st higher peak in mid-February (46,30 FTD) corresponding to the flowering stage of shea tree and a second peak in mid-July (19.20 FTD) corresponding with the shea fruit maturity.

Keywords: Tephritidae - Seasonal abundance - Plant formations - Mango - Shea fruit.

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Fine-scale infestation pattern of *Bactrocera dorsalis* (Diptera: tephritidae) in a mango orchard in Central Mozambique

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In Mozambique, mango (*Mangifera indica* L.) is one of the most important fruit species as source of income and nutrients mainly for the small scale farmers, which constitute the majority. Nevertheless, the occurrence of fruit flies including *Bactrocera dorsalis* (Hendel) is the main factor hampering the production of the crop. Since the invasion of the pest in Africa several studies has been conducted to assess its abundance and controlling measures. Monitoring was conducted weekly during one mango season (2014/15) with Chempac bucket traps baited with torula yeast. Only *B. dorsalis* species were considered for the study. A universal spatio-temporal kriging model was fitted to investigate the spatio-temporal pattern of the fly. Results of the spatio-temporal analysis by kriging interpolation showed high spatial heterogeneity of the fly over time, with the occurrence spreading from the margins of the mango orchard and infesting the whole orchard during the period of peak of abundances reaching densities of more than 500 fly per trap per week.

Keywords: Spatio-temporal - B. dorsalis - Kriging interpolation - Mango orchard.

Ecological control of *Drosophila suzukii* in cherry with the potential dead-end host *Prunus padus*?

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We investigated the potential application of *Prunus padus* as an ecological control of *Drosophila suzukii* in an "attract and kill" strategy. *P. padus* combines two interesting features for this purpose: most *D. suzukii* eggs layed in *P. padus* fruits do not develop into larvae but die (Kill component). Nonetheless, *P. padus* is a very attractive fruit for oviposition of *D. suzukii* (Attract component). We investigated the oviposition preference of *D. suzukii* for *P. padus* versus sweet cherries and the mortality rate of the eggs in the laboratory. Furthermore, we studied the application of this "attract and kill" strategy in semi-field (cages) and field conditions.

In laboratory trials the potential of this trapping plant was clearly determined: complete mortality of eggs laid in *P. padus* was observed. The preference of *D. suzukii* for ripening *P. padus* fruits was significantly higher than for ripening sweet cherries. For ripe fruits the difference in preference was not significant between *P. padus* and sweet cherries. In semi-field trials *P. padus* fruits were able to 'attract and kill' 20% of the layed eggs, but this did not result in a significant reduction in the number of eggs in commercial fruits. In the field, no clear effect of *P. padus* on infestation of sweet cherries was observed. We conclude that *P. padus* is able to 'attract and kill' eggs of *D. suzukii* in lab conditions, but the effect on infestation of commercial fruits in (semi-) field conditions was not significant and too small for practical application.

Keywords: Drosophila suzukii - Prunus padus - Attract and kill - Dead-end trap plant - Sweet cherries.

The firethorn (*Pyracantha coccinea*), a dead-end trap plant for the biological control of the spotted-wing Drosophila (*Drosophila suzukii*)

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The spotted-wing drosophila, *Drosophila suzukii* (Matsumura 1931) (Diptera: Drosophilidae), is an invasive pest which causes important damage to fruit crops. Despite significant economic and environmental harm, no satisfactory means of control have been found yet. One interesting option for the biological control of *D. suzukii* is the use of dead-end trap plants. These are attractive plant species that divert the pest away from infesting the main crop while being lethal for its offspring. Here we explored the efficiency of the firethorn *Pyracantha coccinea* as a dead-end trap plant for *D. suzukii*. We conducted experiments both in controlled laboratory conditions and in growhouses, offering conditions closer to the reality of the field. Our results show that the fruits of *P. coccinea* are highly attractive to *D. suzukii* while being invariably deadly for its offspring. The infestation rate of strawberries, a very attractive fruit commonly infested by *D. suzukii*, was reduced by 40% when firethorn fruits were present in the set-up. We also monitored the survival of *D. suzukii* offspring in *P. coccinea* fruits and observed that mortality occurred before pupation, mainly during the 2nd larval instar, along with a darkening of the larvae's cuticle. Our results demonstrate the potential of *P. coccinea* in the biological control of *D. suzukii*. Indeed, planting firethorn near fruit crops could offer an efficient, durable and low-maintenance solution to reduce the damages caused by *D. suzukii*.

Keywords: Fruit fly - trap crop - Pest management - Biological invasion - Strawberry.

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Post release monitoring of genetic diversity and wolbachia infection of recovered *Psyttalia lounsburyi*, a biocontrol agent of the olive fruit fly in California

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Introduced biocontrol agents are expected to experience a loss in genetic diversity as the result of severe bottlenecks at different stages of biocontrol programs. Hybridization between individuals from different origins may favour the adaptability of the released biocontrol agents by increasing the available genetic variability. However, hybridization can be prevented when the two parents are harbouring different reproductive manipulators, such as the cytoplasmic incompatibility-inducing Wolbachia symbiont. It is thus important to get a better understanding of genetic processes and host-microbe interactions that can affect the establishment of a biocontrol agent.

Bactrocera oleae (Diptera: Tephritidae), is the most serious pest of cultivated olives worldwide. The parasitoid wasp *Psyttalia lounsburyi* (Hymenoptera: Braconidae) collected in Kenya and South Africa, were evaluated in quarantine. Wolbachia infection statuses were assessed for both populations and indicated a double infection in 96% of Kenya population and a single infection (type II) in 50% of the South Africa population.

From 2005 to 2015, more than 60 000 individuals of *P. lounsburyi* have been released in California. Whereas *P. lounsburyi* of Kenya origin represented more than 99% of the parasitoids released, genetic studies of specimens recovered in 2015 revealed that the predominant haplotype is of SA origin and 58% of all the tested individuals harbor the type II Wolbachia symbiont. The fitness cost of Wolbachia coinfections and cytoplasmic incompatibility might be considered as factors limiting the establishment of Kenya population but other factors such as differences in life history traits cannot be excluded.

Keywords: Bactrocera oleae - Biocontrol - Parasitoid - Wolbachia - Hybridization.

Watermelon-infesting Tephritidae fruit fly guild and parasitism by Psyttalia phaeostigma (Hymenoptera: braconidae)

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An ecological guild of Tephritidae fruit flies exploits cucurbit vegetable fruits, tremendously reducing their production worldwide. Knowledge of the composition of the guild of infesting flies in the field and information on their natural enemy species, might improve pest management strategies. Our aim was therefore to identify Tephritidae species infesting the watermelon Citrullus lanatus (Thunb.) Matsum. & Nakai in the Republic of Benin. Morphological and molecular identification of parasitoid species present in the field collections was also done. Infested watermelons were sampled in one of the main watermelon production areas in the country. Adult tephritid flies emerging from watermelons were identified as Dacus bivittatus (Bigot), D. ciliatus Loew, D. punctatifrons Karsch, D. vertebratus Bezzi, Zeugodacus cucurbitae (Coquillet), and Ceratitis cosyra (Walker). In this study period, D. vertebratus was consistently the most abundant species emerging from watermelon. Dacus ciliatus was the second most common species followed by Z. cucurbitae. The number of emerging fruit flies per kilogram of watermelon varied with collection date and month, and was most variable for D. *vertebratus*. Parasitism in the fruit flies was 1.6 ± 6.4% and occurred through one wasp species that was identified as *Psyttalia phaeostigma* Wilkinson (Hymenoptera: Braconidae). This solitary parasitoid is closely related to other members of the P. concolor species complex, some of which are used in biological control. Problems associated with identifying Psyttalia species and possibility of using this wasp as a biological control agent against tephritid flies were discussed.

Keywords: Cucurbitaceae - Citrullus lanatus - Morphological and molecular identification - Parasitoid - Biological control agent.

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Dispersal of *Diachasmimorpha longicaudata* and *Fopius arisanus* (Hymenoptera: braconidae) in smallholder farms: habitat complexity and connectivity

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Tephritidae constitute an important and serious family of dipterans posing enormous economic damage in the horticulture industry. Their control is currently being achieved through Integrated Pest Management in which the use of parasitoids is an integral component. Various parasitoid species have been released in classical biological control programs targeting mostly invasive tephritids. Laboratory and field studies have shown significant success which in some way spells potential triumph for biological control of fruit flies. Two parasitoid species Diachasmimorpha longicaudata (Ashmead) and Fopius arisanus (Sonan) were released in Kenya for the classical biological control of Bactrocera dorsalis (Hendel) and continue being released in various parts of Africa through the African Fruit Fly Program based at *icipe*. In Kenya, percentage of parasitism in lowlands was 33% (F. arisanus) and 14% (D.longicaudata) while in medium-high altitude areas it was 8% for the former and 16% for the later. We discuss these results based on simulations of geospatial mathematical models rooted in habitat complexity, connectivity, and farmer practices in fragmented heterogenous cropping system of Kenya in particular and Sub Saharan Africa in general. The matrix of landscapes, land use, land cover and pesticide use in cropping systems greatly affect parasitoid dispersal. Through empirical and theoretical evidence, this study contributes to biological control of tephritids in fragmented landscapes.

Keywords: Parasitoids - Hymenoptera - Cropping system - Tephritidae - Biological control.



ABSTRACTS FRIDAY 9 OCTOBER

Chemosensory perception and reproduction



The compounds emitted by host-fruits of tephritid species correlate with fruits phylogeny

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Fruit flies meet a diversity of chemical compounds released by their wide range of host-fruits. Their limited sensory capacity suggests the use of an efficient strategy for choosing their nesting sites. Biasazin *et al.*¹ hypothesized that polyphagous species rely on shared volatile compounds among their phylogenetically diverse host-fruits. Contrarily, oligophagous species specialized on Cucurbitaceae or Solanaceae might use specific volatile compounds of their hosts². This study aims at depicting the chemical diversity of fruit volatile emissions and their correlation with the phylogeny of host-fruits. We analyzed the volatilomes of intact and sliced fruits from 28 species including six Cucurbitaceae, five Solanaceae and four Myrtaceae infested by various tephritid species with gas chromatography coupled to mass spectrometry. We quantified 468 and 629 volatile compounds in intact and sliced fruit emissions respectively, of which 376 and 465 were putatively identified. Phylogenetic principal component analysis showed that the emissions of sliced fruits correlate better with fruit phylogeny than the emissions of intact fruits. The presence of damaged fruits in an area might contribute to host selection by fruit flies. The analysis revealed specific compounds of fruit families. We also observed that the chemical emissions of Cucurbitaceae are more homogenous than other fruit families. This finding could explain why several independent evolutionary steps led to a specialization of tephritid species to this family of fruits. Thus, a simple strategy relying on small number of volatile compounds might be sufficient for fruit flies to find nesting site.

Keywords: Fruit fly - Host-range - Nesting site - Volatilome.

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Using evolutionary clues to infer the ecological importance of semiochemicals in tephritid-host fruit interactions

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Insects explore their chemical environment with a limited number of olfactory receptors sensitive to a subset of the compounds released by plants. However their receptive range is frequently underestimated due to lack of sensitivity and bias of gas chromatography - electroantennographic detection (GC-EAD), the technique widely used to assess olfactory sensitivity of insects. Recent methodological upgrades - multi-probe recordings¹ and modulation of the GC output - overcame these limitations and unveiled more active compounds than initially considered. We suggest the use of evolutionary clues to drive the search of stronger and more specific attractive blends. The range of compounds detected by an insect emerged from opposite evolutionary processes. Receptors of compounds with fundamental importance to the insect undergo a purifying selection. It results in a conservation of olfactory sensitivities among species². Contrarily receptors involved in host specialization underwent a positive selection. Thus, the ecological importance of each semiochemical might be estimated through a cross-species comparison of olfactory sensitivity. We compared the antennal response of the tephritid species Bactrocera zonata, Bactrocera dorsalis, Ceratitis capitata, Ceratitis catoirii, Ceratitis quilicii, Dacus demmerezzi, Neoceratitis cyanescens and Zeugodacus cucurbitae to compounds emitted by mango and strawberry-guava fruits. Several compounds from these fruits induced a response in all the tephritid species tested. These compounds might have a fundamental role among tephritid species for host finding. We will also show preliminary results on compounds that evoked a differential response among tephritids.

Keywords: Tephritids - GC-EAD - Attractants - Olfactory systems - Kairomones.

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Olfactory preference of *Drosophila suzukii* shifts between fruit and fermentation cues over the season: effects of physiological status

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Worldwide monitoring programs of the invasive fruit pest Drosophila suzukii Matsumura (Diptera: Drosophilidae), using fermentation baits like apple cider vinegar (ACV), revealed a counterintuitive period of low trap catches during summer, followed by an autumn peak. We demonstrated that ACV baited traps indeed provide a distorted image of the D. suzukii population dynamics as we could capture higher numbers during this "low capture period" with synthetic lures. It was hypothesised that the preference of *D. suzukii* populations for fermentation cues is most pronounced during autumn, winter and spring, while the flies prefer fresh fruit cues during summer and that this seasonal preference is related to the changing physiology of the flies over the season. Therefore, the preference between fermentation cues (ACV) and host fruits (strawberries) and the effect of physiology (sex, seasonal morphology and feeding, mating and reproductive status) was investigated both in olfactometer-based laboratory experiments and a year-round field preference experiment. In olfactometer experiments we demonstrated that protein-deprived females, virgin females and males show a strong preference for fermentation cues, while fully fed reproductive summer morph females generally prefer fruit cues. These findings indicate that D. suzukii is attracted to fermentation volatiles in search of (protein-rich) food and to fruit volatiles in search of oviposition substrates. Winter morph and starved females displayed indiscriminating olfactory behaviour. In the field preference experiment, the hypothesised seasonal shift between fermentation and fruit cues was confirmed. This shift appeared to be highly temperature-related and was similarly observed for summer and winter morphs.

Keywords: Drosophila suzukii - Monitoring - Olfactory Behaviour - Physiological Status - Seasonal Changes.

Prey can detect predator through chemical cues modifying their oviposition: oviposition avoidance of flies towards Dufour&poison gland chemicals from weaver ant

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Predator detection and avoidance are crucial traits for prey survival mediated by semiochemicals. The predatory African weaver ant, *Oecophylla longinoda* (Hymenoptera: Formicidae) produces semiochemicals which influence the behavior of certain fruit fly species. Here, we aimed to investigate and compare the role of *O. longinoda* semiochemicals on the oviposition responses of two fruit fly species; the invasive species *Bactrocera dorsalis* and the African native species *Ceratitis cosyra* (Diptera: Tephritidae). We carried out dual-choice assays with ant-exposed and unexposed mangoes, ant whole body, thorax, head and abdomen and gland (Dufour, poison, rectal and sternal) extracts. Our results show that both fruit fly species avoided and laid fewer eggs on weaver ant-exposed than unexposed mangoes. Subsequent assays with mango discs treated with different extracts of body parts showed that hexane extracts of ant abdomens reduced oviposition responses in only *C. cosyra*. Additionally, mango discs treated with extracts of exercised Dufour and poison gland in hexane elicited stronger oviposition reduction responses in *C. cosyra* than in *B. dorsalis*. These results suggest that weaver ant gland compounds could play a role in the oviposition avoidance behaviour of both fruit fly species.

Keywords: Bactrocera dorsalis - Ceratitis cosyra - Oecophylla longinoda - Repellent - Pheromones.



ABSTRACTS OF POSTERS



Overwintering dynamics of the mediterranean fruit fly in Central Dalmatia of Croatia

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The Mediterranean fruit fly, *Ceratitis capitata* (Diptera: Tephritidae), is a polyphagous species that has recently expanded its range in Central Europe. However, the overwintering capacity of the medfly stages in those areas remained unexplored. In the frameworks of the HORIZON 2020 '818184 FF-IPM' project, we assessed the overwintering capacity of adults and pupae in three overwintering sites (open field, storehouse in field, and basement in urban area) in Split (Dalmatia region, Croatia) during the winter period 2019-2020. For this purpose, we used wild flies from Split population. Ten cages with adults (0-1 day old) (5 $\Im \Im$ and 5 $\Im \Im$ /cage) were transferred into the three sites at three dates (30/10/2019, 19/11/2019, 18/12/2019). Adult mortality was recorded every 2-3 days. In case of pupae, ten bottles with 2-5 day old pupae (20-40 pupae/bottle) were placed in the three overwintering sites at 28/10/2019, 6/11/2019 and 5/12/2019. Pupal survival and adult emergence rates were recorded every 2-3 days. Newly emerged adults were transferred in pairs into demographic cages and kept at the same overwintering sites. Adult survival and female oviposition were recorded daily. Our results revealed that a) a few adults from the basement in urban area remained alive until the end of spring, while no adults from storehouse in field survived during spring. Adults from open field died until the end of March, b) adult emergence of overwintering pupae concluded in the middle of January, and c) females emerged of overwintering pupae remained alive until the early of August.

Keywords: Adult Emergence - Ceratitis capitata - Invasion - Survival - Winter.

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Comparative microbiomics of tephritid frugivorous pests (Diptera: Tephritidae) from the field: a tale of high variability across and within species

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Despite the increased interest in the gut microbiome of tephritid fruit flies, our present knowledge is largely based on the analysis of laboratory strains. In this study, we present a comparative analysis of the gut microbiome profiles of field populations of ten African and Mediterranean species with different dietary breadth. For each, third instar larvae were sampled from different locations and host fruits and compared using 16S rRNA amplicon sequencing and a multi-factorial sampling design. We observed considerable variation in gut microbiome diversity and composition both between and within fruit fly species. A "core" microbiome, shared across all targeted species, could only be identified at most at family level (Enterobacteriaceae). Only a few bacterial genera (Klebsiella, Enterobacter and Bacillus) were present in most, but not all, samples, with high variability in their relative abundance. For seven bacterial genera a distinct higher relative abundance could be found in five fruit fly species: Erwinia in Bactrocera oleae, Lactococcus in B. zonata, Providencia in Ceratitis flexuosa, Klebsiella and Rahnella in C. podocarpi and Acetobacter and Serratia in C. rosa. With the possible exception of *C. capitata* and *B. dorsalis* (two most polyphagous species considered), no obvious relationships between fruit fly dietary breadth and microbiome diversity or abundance patterns could be detected. Our results did not suggest straightforward differences between the microbiome profiles of species belonging to Ceratitis and the closely related Bactrocera/Zeugodacus. This study provides base line information for future investigations in the possible functional role of the observed associations.

Keywords: Bactrocera - Ceratitis - Zeugodacus - Enterobaceriaceae - Gut microbiome.

You are what you eat: host plant determines microbiome composition and structure in wild melon fly (Diptera, Tephritidae: *Zeugodacus cucurbitae*) larvae

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Phytophagous insects are among the most diverse group of eukaryotes. Their diversity seems to have arisen as a result of plant-insect interactions but underlying mechanisms are largely unknown. In this respect, insect-associated microbial symbionts might be important as they are ubiquitous and known to play crucial roles in various processes such as nitrogen metabolism, vitamin supplementation and detoxification of plant allelochemicals. As such, it is thought that microbial symbionts might play a key role in host plant utilization and host shifts in herbivorous insects. In this study, we investigated the impact of simulated host plant shifts on the larval microbiomes of the oligophagous cucurbit feeder *Zeugodacus cucurbitae*. Larvae from two wild populations collected in La Réunion (France) were raised on two conventional cucurbit host plants (ivy gourd; squash) and on two unconventional hosts (eggplant, Solanaceae; mango, Anacardiaceae). Our results show significant changes in microbiomes of larvae feeding on different host fruits, and identified several differentially abundant bacterial genera between host plants. We also identified several metabolic functions that larval microbiomes in host plant utilization and in host switching to unconventional host plants.

Keywords: Plant-insect interactions - Microbial symbionts - Host switch.

Effects of host fruit, temperature and *Wolbachia* infection during immature development on the demographic traits of emerging adult Mediterranean fruit flies

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Immature development and survival of *Ceratitis capitata* (Diptera: Tephritidae) (medfly) are greatly affected by temperature and host fruit species. Additionally, the endosymbiont Wolbachia pipientis induces several alterations on the bio-demographic traits of its hosts, including transinfected ones, such as C. capitata. However, little is known on how immature development under different conditions (temperature, nutrition) may affect the demographic traits of emerging adult medflies. We studied the effect of three different temperatures (15, 25 and 30°C) during the development of immature stages within two hosts (apple-Golden Delicious, bitter orange) on the demographic traits (lifespan, fecundity) of emerging adults of *C. capitata*. We used four different medfly populations either infected or uninfected with Wolbachia (a) 'Benakeio', uninfected, laboratory population, (b) '88.6', Benakeio line carrying the wCer2 Wolbachia strain, (c) 'S10.3', Benakeio line carrying the wCer4 Wolbachia strain and (d) 'F9' wildish population originated from field infested apples. Adult mortality and female fecundity were recorded daily. Host fruit did not affect adult survival in none of the medfly populations, regardless of the temperature that fruits were exposed to. The higher the temperature, the longer was the lifespan of emerging adults. 'F9' medflies outlived all the other medfly populations/strains tested, regardless of host species and exposure temperature. None adult 'S10.3' medfly emerged when larvae developed in fruit exposed to 30°C. Females of '88.6' and 'Benakeio' exhibited higher fecundity than 'F9' and 'S10.3' females. Females of F9 had higher pre- and post-oviposition period compared to the other medfly populations.

Keywords: Ceratitis capitata - Lifespan - Fecundity - wCer4 - wCer2.

How to partition the effects of symbionts on *Drosophila* resource acquisition and developmental plasticity and why it matters

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Many symbionts can provide nutrients to their host and/or affect its phenotypic plasticity. Such symbiont effects on host resource acquisition and allocation are often simultaneous and difficult to disentangle. Here we partitioned microbial symbiont effects on fly resource acquisition and allocation using a new framework based on the analysis of a well-established trade-off between host fitness components. We analyzed the effect of eighteen symbiotic yeast on the larval development of *Drosophila suzukii, simulans* and *melanogaster* larvae in field-realistic conditions. We showed yeast had similar effects on the resource acquisition in *Drosophila suzukii, D. simulans* and *D. melanogaster* but species-specific effects on developmental plasticity of either larval development speed or adult size. These differences may inform on the ecology of *Drosophila* flies and illustrate why distinguishing between qualitatively different effects of microorganisms on hosts may help to understand and predict symbiosis evolution. Moreover, results from this framework can be used to improve insect mass-production (e.g. for the Sterile Insect Technique) so as to fine-tune insect vigor and phenotype to contextual needs.

Keywords: Drosophila - suzukii - Drosophila melanogaster - Yeast - Symbiosis.

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Insect plasticity to climate change: effect of gut symbionts on starvation resistance and thermal tolerance of tephritid fruit flies (Diptera, Tephritidae)

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As climate change increases global temperatures, the threat of invasive insect species might increase due to tropical and subtropical insects expanding their range into temperate areas. In this context, environmental stress resistance, allowing insects to adapt to novel or variable climatic conditions, is the most important factor that contributes to niche partitioning and biogeographic patterns. Moreover, the ability of an insect to withstand periods of food deprivation or limitation is also considered as a key driver of invasion success. Synergies between the insect host and its gut microbiome could also affect the capability of providing plastic responses to environmental changes. Exploiting two model species in invasion biology, Bactrocera dorsalis and Zeugodacus cucurbitae (Diptera: Tephritidae), we assessed plastic changes in some of their life history traits (survival, longevity and fecundity) for adaptations to thermic and starvation stress and the role of their gut symbionts in shaping the ability of hosts to tolerate these stressful situations. We compared cold and heat tolerance of axenic (diet with antibiotic) and non-axenic (diet without antibiotic) tephritid fruit flies under three adult diet treatments: sucrose only (20%), yeast hydrolysate only (20%), or sucrose and yeast hydrolysate at 3:1 ratio. Understanding of insect starvation biology under thermic stress and the role of gut symbionts in invasive insect plasticity can ameliorate the prediction of the consequences of climate change on insect dispersal and establishment.

Keywords: Climate Change - Cold-Heat Adaptation - Gut Symbiont - Plasticity - Starvation Resistance.

Experimental selection in *Ceratitis cosyra*: the interplay between late sex, short lives and oxidative stress

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The oxidative damage caused to cells by reactive oxygen species (ROS) is one of several factors implicated in causing ageing. Oxidative damage may also be a proximate cost of reproductive effort that mediates the trade-off often observed between reproduction and survival. However, how the balance between oxidative damage and antioxidant protection affects life-history strategies is not fully understood. To improve our understanding, we selected on female reproductive age in the marula fruit fly, *Ceratitis cosyra*, and quantified the impact of selection on female and male age-dependent mortality, female fecundity, male sperm transfer, calling and mating. Against expectations, upward-selected lines lived shorter lives and experienced some reductions in reproductive performance. Selection affected oxidative damage to lipids and total antioxidant protection, but not in the direction predicted; longer lives were associated with elevated oxidative damage, arguing against the idea that accumulated oxidative damage, suggesting that oxidative damage may be a cost of reproduction, although one that did not affect survival. Our results add to a body of data showing that the relationship between lifespan, reproduction and oxidative damage is more complex than predicted by existing theories.

Keywords: Experimental Selection - Oxidative Stress - Antioxidant - Lifespan - Reproduction.

Absence of premating isolation between geographic isolated *Rhagoletis cerasi* populations

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Premating reproductive isolation is assumed to be an early-acting isolating mechanism between ecologically divergent populations. In *Rhagoletis cerasi*, the geographical variation in pupae dormancy termination facilitates the synchronization of adult emergence with the cherry fruit phenology patterns of local hosts. Given that the allochronic isolation of *R. cerasi* adults from ecological divergent populations is a potential factor of premating isolation, we compared the assortative mating patterns of a) pairs with same adult phenology patterns and either low gene flow ('Dossenheim vs Dafni') or moderate gene flow rates ('Thessaloniki vs Agia'), and b) pairs with different adult phenology patterns and either low gene flow ('Dossenheim vs Kala Nera') or moderate ('Dafni vs Kala Nera') or high gene flow rates ('Dafni vs Pertouli'). The relative importance of homotypic mating pairs in relation to the heterotypic ones was measured by the global IPSI estimator of sexual isolation. Sexual selection estimates (W) were calculated for each population, in males and females separately, based on the relative mating success (sexual fitness) of each population with respect to the most successful one. Our results reveal random mating (IPSI ≈ 0, P>0.005) between all cross combinations (see above), regardless of their genetic distance and adult phenology patterns. However, we found significant low values of sexual fitness for males from Dossenheim in 'Dossenheim vs Kala Nera' cross combination (W=0.523 ± 0.111, P<0.001), as well as for males from Pertouli (W=0.588 ± 0.132, P=0.007) and females from Dafni (W=0.534 ± 0.122, P=0.002) in 'Dafni vs Pertouli' cross combination.

Keywords: Assortative Mating - European Cherry Fruit Fly - Prezygotic Isolation - Sexual Isolation - Sexual Selection.

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LIFE - History of two Mediterannean fruit fly populations on key overwintering hosts and different temperatures

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Temperature and host are significant predictors of survival and development of the immature stages of the Mediterranean fruit fly, *Ceratitis capitata* (Diptera: Tephritidae). Bitter oranges and apples are considered key fruit hosts. In this study (in the frameworks of the Horizon 2020 "818184 FF-IPM" project), we used two medfly populations from Northern Greece and Austria to examine a) the developmental responses of the immature stages to constant and fluctuating temperature regimes reared in both apples and bitter oranges, and b) the effects on survival and reproduction of the emerging adults. For this purpose, artificially infested fruits (10 eggs/fruit) were kept at a) three constant temperatures (15°C, 20°C, 25°C) and b) two thermocycles (FTR1: 2 days at 20°C and 2 days at 7°C, FTR2: 2 days at 20°C and 6 days at 7°C) until pupation and adult emergence. Upon emergence, pairs of adults $(1 \bigcirc$ and $1 \checkmark)$ were transferred individually into demographic cages and then at 25°C. Adult survival and female oviposition were daily recorded. Our results revealed that host, population, rearing temperature, the interactions of host with temperature and host with population were significant predictors of egg-to-pupa survival. Pupation rate and pupal survival were affected by both host and rearing temperatures, while adult emergence rates were only affected by rearing temperatures. No adults emerged from the FTR2 treatment while only a few adults emerged at 15°C and FTR1 treatment. Lifespan, fecundity, and reproductive periods of adults emerged from 25°C and 20°C rearing conditions were significantly affected by host, temperature, and population.

Keywords: Demography - Fecundity - Fluctuating Temperature regimes - Immature Stages - Lifespan.

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Maternal age and duration of larval development affect the demographic characteristics of adult Mediterranean fruit flies

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Temperature, relative humidity, host fruit and crowding, acting during immature development, affect larval development and the fitness traits of emerging adults in *Ceratitis capitata* (Diptera: Tephritidae). Moreover, the majority of fertile eggs are laid during the first third of females' adult life. However, no information exists on whether the mother's age and the variability of larval developmental time affect the fitness of emerging adults. We studied under constant laboratory conditions the effects of the (a) mother's age (young-10-days, old-40-days) and (b) larval developmental duration (short, long), on the demographic traits (lifespan, fecundity) of emerging adults. Eggs were deposited in artificial oviposition substrates by females of a semi-wild (F₂) population and were artificially implanted in Golden Delicious apples (20 eggs/apple) maintained at 18±1°C and 50±5% relative humidity (R.H). Pupae were sorted by larval developmental duration and their dimensions (length/ width) were measured. Emerging adults were paired in individual cages with access to adult diet and water. Adult mortality and female fecundity were recorded daily. Old-40-days females yielded larger offspring than young-10-days female medflies, regardless of the duration of larval development. Immature developmental duration (egg to pupa) lasted longer for the offspring of young than for those of old females. Adult flies with short larval developmental duration lived longer than flies with long larval development, regardless of their mother's age. No significant differences were observed on the longevity between progeny of old and young females. Neither the duration of larval development nor the mother's age affected the fecundity of female progeny.

Keywords: Ceratitis capitata - Lifespan - Fecundity - Immature Stages - Progeny.

Effect of Semio-chemicals (Methyl Eugenol) on calling behaviour and mating competitiveness of laboratory reared peach fruit fly *Bactrocera zonata*

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The Sterile Insect Technique is highly dependent on the field performance of the mass-reared, sterilized, and released insects. Wing fanning is a predominant male sexual behaviour reported in several *Bactrocera* spp. Males of the majority of *Bactrocera* spp. are attracted to natural compounds known as semio-chemicals. The objective of this study was to determine the effect of exposure to methyl eugenol on (i) calling behaviour and (ii) mating competitiveness of *Bactrocera* zonata (Saunders) (Diptera: Tephritidae). Significantly more calling was observed with ME-fed male flies as compared to untreated males (F= 7.80, df = 37, P= 0.012). ME-fed male flies started calling earlier (F= 6.76, df= 37, P= 0.000) on Day 6 as compared to untreated flies which started calling on Day 8. Percentage of flies calling increased significantly with age up to Day 28 (F= 5.93, df = 59, P = 0.00), then the percentage of calling decreased. Exposure to ME (F= 53.25, df = 59, P= 0.000) had a significant effect on calling behaviour. In the field cage experiment, more than 50 % matings was obtained with ME-fed males as compared to 16 % with untreated males (F= 23.31, df = 5, P = 0.008). ME-fed flies started mating earlier (17:10) as compared to untreated flies which started mating twenty minutes later. Earlier sexual maturity and enhanced mating competitiveness of ME-fed flies has a major role to play in improving the effectiveness of an SIT programme for the suppression of the peach fruit fly.

Keywords: Bactrocera zonata - Sterile Insect Technique - Methyl Eugenol - Calling Behavior - Mating Competitiveness.

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Marula flies can take the heat and the chill: Upper and lower lethal temperatures for *Ceratitis cosyra* (Walker) (Diptera: Tephritidae)

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The marula fly, *Ceratitis cosyra* (Walker) (Diptera: Tephritidae), is an Afrotropical species of phytosanitary concern that affects mango production. Development of *C. cosyra* is temperature-dependent, but its thermal tolerance has not yet been defined. We determined the lower (LLT) and upper lethal temperatures (ULT) of *C. cosyra*. Flies were reared at $21\pm1^{\circ}$ C. Vials containing ten males or females (n = 5 for each sex) were exposed to a temperature range of 14 to -10° C for the LLT test, and 28 to 52° C for the ULT test, at increments of 4°C. Vials containing the flies were immersed for 2 hours in a programmable water bath at one test temperature. Flies recovered at 25°C for 24 hours before survival was recorded. Data were analysed using separate generalized linear models with binomial error distribution to determine the effects of temperature and sex on fly survival. The fitted models were used to estimate the LLT and ULT, which were defined as the temperatures causing 50% mortality in each test. Survival of *C. cosyra* was significantly affected by temperature but not by sex. The LLT of -6°C and ULT of 43°C for *C. cosyra* is a slightly wider tolerance range than those recorded from *Ceratitis capitata* and *Ceratitis rosa*. These results support suggestions that the distribution of this species is more strongly affected by availability of its host than by the physical environment.

Keywords: Ceratitis - Thermotolerance - Hardening.

Short-term adaptation does not alter the evolutionary fate of populations in the Mediterranean fruit fly

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Relatively short-term differences in genetic history can play a major role in the capacity of species to respond to novel conditions, but the effects can be complex and require further investigation1. We determined the importance of historical contingency on adaptation in the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae) by using a two-step experimental evolution approach. From a single lab-adapted culture of *C. capitata*, 10 replicate lines were split into two treatment groups. One group was exposed to six generations of selection for ethanol vapour resistance and the other was kept under the same conditions as the original culture population for the same duration. Thereafter, each replicate line was divided into two groups either receiving the same selection treatment or selected for desiccation resistance for six generations. Fecundity, egg viability, body mass, ethanol stress resistance and desiccation stress resistance were tracked throughout the selection experiments. *Ceratitis capitata* can adapt to ethanol vapour stress with no perceptible trade-off in fecundity or egg viability. Furthermore, historical selection for ethanol vapour resistance did not subsequently affect the capacity to develop increased desiccation resistance. This ability to respond to stresses without apparent trade-offs could be a reason why this species is a globally invasive pest of horticulture.

Keywords: Experimental Evolution - Stress Resistance - Trade-offs.

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Mitochondrial dna marker analysis in laboratory colonies of the *Ceratitis* far complex

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The Ceratitis FAR species complex currently consists of the African species C. anonae, C. fasciventris, C. quilicii and C. rosa. All members of the complex are economic important pests since they infest and destroy a variety of fruits and vegetables. The discrimination of the complex's species is challenging due to the absence of robust morphological differences and the ongoing gene flow among them, causing problems to their management and control efforts. Therefore, there is great interest for the exploration of their phylogenetic relationships and the development of robust molecular markers for their identification. Nowadays, it has become evident that resolution of species complexes requires multidisciplinary approaches, ideally applied on the same specimens, in the context of integrative taxonomy. Here, we present the analysis of three mitochondrial sequences (COI-5', COI-3' and ND6) in specimens of five well-characterized FAR colonies: two of C. rosa (originating from Kenya and South Africa), two of C. quilicii (originating from Kenya and South Africa) and one colony of C. fasciventris (F2) (originating from Kenya). The analyzed colonies were maintained in the Joint FAO/ IAEA Insect Pest Control Laboratory (Seibersdorf, Austria) and they have been used as reference laboratory material in several research programs. The above results are part of an ongoing effort, also including cytogenetic and whole mitogenome analysis, aiming to provide useful characters that could contribute to the comparative analysis and the resolution of the FAR species complex when used in the frame of integrative taxonomy.

Keywords: Tephritidae - Species identification - Mitochondrion - Integrative taxonomy.

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Effect of gamma–irradiation, antibiotic treatment, and probiotic enriched diets on cuticular hydrocarbon profiles of mass-reared *Ceratitis capitata* males

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The medfly (*Ceratitis capitata*) is one of the major agricultural pests controlled through sterile insect technique programs (SIT). However, mass-rearing, domestication and gamma irradiation of medfly used in SIT can negatively impact fly quality and performance. Symbiotic bacteria supplied as probiotics to mass-reared fruit flies may help to overcome some of these issues. Until recently, the majority of studies investigating medfly gut communities have focused on several aspects related to the rearing efficiency and biological quality of the medfly such as host fitness and sexual competitiveness. While, their impact on chemical communication such as cuticular hydrocarbon (CHCs) remains unknown. Hence, the aim of this study was to investigate factors affecting male CHCs profiles of *C. capitata* to increase the efficacy of SIT.

Our result revealed substantial qualitative and quantitative differences between males CHCs profiles of *C. capitata* from a laboratory culture and wild males collected from orange orchard. The CHCs comparison revealed many compounds, some of which were reported for the first time as part of the *C. capitata* male volatile constituents. Our observation of the high complexity of the medfly male CHCs profile agrees with previous studies. All disruption of the microbiota through antibiotic treatment or irradiation affects CHCs profiles suggesting a possible implication of microbiota disturbance on mate choice decisions. Also probiotic enriched diets affect their CHCs profiles in comparison to untreated controls.

These findings are discussed in relation to the mating behavior of the medfly and to the effectiveness of released sterile males in SIT programs.

Keywords: Ceratitis capitata - Microbial symbionts - Gamma–irradiation treatment - Probiotic enriched diets - Cuticular hydrocarbons.

Metabolomic profiling with ¹H NMR spectroscopy of sterile male of Mediterranean fruit fly *Ceratitis capitata*

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The sterile insect technique is the most environment friendly insect pest control methods ever developed for the suppression or eradication of a number of insect pests such as the *Ceratitis capi*tata. Irradiation, remains the most practical tool to sterilize mass-reared insects, radiation-induced mutations are lethal in reproductive male cells, while males remain sexually competitive once released in the field. Characterization of the metabolic shift associated with gamma irradiation exposure in sterile males would be helpful to identify the affected metabolites that have a primordial role during the mating process. In this work, a metabolomic study was performed to characterize the global metabolic changes for Medfly sterile males treated at 0, 70, 90, 110 and 145 Gy. We utilized an NMR-based metabolomic approach in combination with multivariate analysis (PCA) to profile the metabolites. The integral data was found to cluster into four different groups representing untreated males (0 Gy) as the first group, the second group includes males treated at 70 and 90 Gy, the third group included males treated at 110 Gy and the last represents males treated at 145 Gy. The results show the PCA score plots for all treated males taken together with PC1 explaining 35.7% of the variation, PC2 explaining 15.9% of the variation and PC3 explaining 11.6% of the variation between groups. Marked disturbances in the metabolites within somatic cells can lead to biological malfunctions and thus diminish the competitiveness and mating behavior of the irradiated males, which will decrease the effectiveness of the SIT program.

Keywords: Ceratitis capitata - Gamma radiation - 1H NMR spectroscopy.

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Screening of potential probiotic activities of bacterial isolated strains from *Ceratitis capitata* guts for incorporation in larval diet based on SIT application

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The Mediterranean fruit fly, *Ceratitis capitata* (Diptera: Tephritidae), is an important economic pest worldwide causing direct crop damage. One of the most successful control strategies for this pest is the application of the sterile insect technique. Several studies have shown that irradiation affects the Vienna8 Genetic Sexing Strain sterile males performance when competing with wild males for wild females. The exploitation of the intestinal microbiota by administration of members of the fly's community as probiotics in the larval diet have positively influenced the sterile insect performance. Hence, in the current study, bacterial strains were isolated from *C. capitata* wild strain guts and were identified using ITS-PCR and 16S rRNA sequencing method. The isolated strains were evaluated for their probiotic potential by *"in vitro"* (tolerance to irradiation, cell surface hydrophobicity, cellular auto-aggregation and co-aggregation, biofilm formation and EPS production) and *"in vivo"* (*Enterobacteriacea* load in larval diets at the 12th day after eggs seeding, eggs to adult development, pupal weight, flight capacity, survival and mating success) tests. Finally, the candidate probiotic strains were selected by statistical analysis of their *"in vitro"* and *"in vivo"* tests data using principal component analysis (PCA). The combination of the two PCAs allowed the selection of *Enterobacter* sp., *Lactococcus lactis* and *Klebsiella oxytoca* as potential probiotic candidates to integrate in the larval diet.

Keywords: C. capitata - SIT - Intestinal microbiota - Probiotic potential - Quality control parameters.

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Non-host status of litchi, Litchi chinensis Sonn. (Sapindaceae) to the oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) in Mozambique

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Phytosanitary measures present significant barrier to the export of fresh fruits of Litchi chinensis cultivar "Mauritius" from Mozambique due to the occurrence of Bactrocera dorsalis. This study assessed the infestation of Bactrocera dorsalis on fresh litchi fruits at harvest maturity stage to determine its host status. Litchi fruits were collected from Manica and Maputo provinces in November 2015 and 2016 and then reared in laboratory for adult fruit flies emergence. Field cage experiments were carried out at the same sites covering the trees and/or bunchs with mosquito netting and then exposed to 25, 50 and 100 gravid females for oviposition. At both sites, no fruit fly infestation was recorded on litchi fruits under natural or artificial infestation. However, Bactrocera dorsalis emerged from litchi fruits previously infested by litchi moth, Cryptophlebia peltastica or mechanically damaged with infestation of 0.15 - 0.65%. The results suggest that litchi fruits can only be infested by B. dorsalis if they present previous mechanical damage (cracks) or infestation by other insects (Cryptophlebia peltastica). The non-host status of litchi for B. dorsalis may be due to skin (the pericarp) hardness which prevents oviposition of fruit flies. Therefore, litchi fruits at harvest stage are extremely unlikely to be natural or conditional host for B. dorsalis. Litchi fruits should be carefully inspected before export and discard all fruits showing mechanical damage and or symptoms of insect infestation because such damages can allow infestation by B. dorsalis and pose the risk of inadvertent translocation of the insect during export.

Keywords: Litchi chinensis - Bactrocera dorsalis - Host status - Infestation.

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Development of effective, economically viable and sustainable strategies for management of *Drosophila suzukii – DS2 project*

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The spotted wing drosophila (SWD), Drosophila suzukii, is a key pest on berry fruits and sweet cherries in France. Management with insecticides is not a reliable strategy because of inconsistent efficacy, and SWD high-density population. Furthermore, environmental concerns due to insecticides use, and ban of highly toxic active substances in France, force stakeholders to develop alternative levers for the management of SWD. DS2 project brings together academic and applied research, extension services, and agricultural education to develop and transmit to growers new tools and strategies to control SWD, in order to secure production and reduce the use of insecticides. Several solutions are being studied, focused on strawberry and cherry productions, at the level of the landscape and the plot. At landscape level, we assess the possibility to develop classical biological control by releasing the exotic parasitoid *Ganaspis* cf. brasiliensis to reduce SWD population in the environment. First results indicate high specificity of the two tested strains of the parasitoid and its ability to establish on strawberry crop, in semi-field condition. At the plot level, we investigate the interest of physical barriers with the use of peripheral nets to protect cherry trees. We also assess the efficacy of dead-end trap plants to deter from strawberry crop, SWD females ready to lay. Dead-end trap plants have shown to be very effective to reduce egg laying on strawberry in a laboratory experiment. New experiments in semi-field and field conditions are conducted during the DS2 project to confirm the interest of this trap plant.

Keywords: Drosophila suzukii - IPM - Biological control - iInsect-proof nets - Trap plants.

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Host ranges and infestation indices of fruit flies (Diptera: tephritidae) in Mpumalanga and Limpopo, South Africa

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An important aspect of pest management is to have accurate information on the host range of pest species. Numerous types of insect pests have a negative impact on fruit and vegetable production in South Africa, and fruit flies (Diptera: Tephritidae) are among the most important. Fruit from 40 exotic and 20 indigenous plant species were sampled in Limpopo and Mpumalanga. Fruit were incubated to determine the presence of fruit fly species. Dacus bivittatus (Bigot) and Dacus ciliatus Loew were reared from fruit of the family Cucurbitaceae. The invasive species, Bactrocera dorsalis (Hendel) was reared from 19 different plant species belonging to 11 families. Mango and guava were identified as important hosts for *B. dorsalis*. High infestation indices of *Ceratitis capitata* (Wiedemann) were found in Coffea species. Ceratitis quilicii De Meyer, Mwatawala and Virgilio and Ceratitis rosa Karsch, which are two closely related species, were found to share the same host plants. However, C. rosa dominated in fruit sampled at the ARC-Tropical and Subtropical Crops experimental farm at Mbombela. High infestation indices of *C. rosa* were found in exotic fruit of the family Myrtaceae. Stem fruit, Englerophytum magalismontanum (Sond.) T.D. Penn. of the family Sapotaceaee was an important indigenous host for C. quilicii and C. rosa. Ceratitis cosyra (Walker) seemed to have a more restricted host range in comparison to the other economically important *Ceratitis* species. The wide availability of host plants and the impact of fruit flies on horticulture call for the development of sustainable area wide management strategies.

Keywords: Tephritidae - Hosts - Ceratitis - Bactrocera - Dacus.

The Pervemac II project and its actions regarding the sustainable use of pesticides on agricultural production, food safety and consumers health in Azores

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The overall objective of the PERVERMAC II project is to promote a sustainable use of pesticides in the agricultural production and ensure food security in the archipelagos of the Macaronesian region (Azores, Madeira, Canaries and Cape Verde). In all the work programed, ensuring the safety and health of farmers that apply pesticides in their cultures, through the quantification of residues level in the agricultural products locally produced and imported from the main crops and at the same time minimizing the risk of health of the consumers and decreased environmental contamination will be achieved. By sampling and analyzing the level of residues in the agricultural products collected during the last four years (2017 to 2020) was possible to ensure food safety of the Azorean population. There were also made food surveys to obtain the real proportion of agricultural products in our diet and the correlated level of pesticides residues in the food intake by humans. Fortunately, on most products analyzed there were not residues found and those when found were under the limit levels. These actions for sensitizing the populations were made for the adoption of good food or diet content and promoting actions concerning the implementation of organic production. Through actions of knowledge and technology transfer for the farmer and the technicians ensured the adoption and implementation of integrated protection measures, promoting the sustainable use of pesticides by the farmers that implemented alternative means of protection against the major phytossanitary problems of their crops.

Keywords: Residues - Pesticides - Health - Food safety - Sustainable practices.

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Adoption factors and dynamics of fruit flies regional IPM

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Area wide IPM (AW-IPM) is an effective approach for efficient large scale suppression of fruit flies, but in spite of its proven benefits and continuous research and outreach promotion, adoption levels are often still low, especially in the developing world. Analysis of adoption factors and dynamics was done in two different AW-IPM case studies, Medfly (*Ceratitis capitata*) in deciduous orchards in Israel and oriental fly (*Bactrocera dorsalis*) in mango in Kenya, representing a vast array of socioeconomic and local conditions.

Using a simple methodology of analyzing separately extrinsic and intrinsic factors was found to be an efficient tool for identifying major obstacles that should be considered in design and management of projects. Each case study presented different obstacles to IPM adoption, mainly risk avoidance in Israel and equipment price and availability in Kenya, and both showed the efficiency of incentives and close advisory in promoting AW-IPM. In parallel, the common principles of collective action in use of public goods were found relevant to AW-IPM in both case studies, and additional principles of gradual transition and project oriented leadership were suggested. The results demonstrated the importance of relating also to considerations of perceptions and behavior at villages and growers' groups level beyond those of individual growers, and to the effect of non-participants in the region. The study also demonstrated the benefits of analyzing adoption dynamics and factors also at a sub region level.

Keywords: Area wide IPM - IPM adoption - Medfly - Oriental fly.

Potential of some cultural levers for fruit fly management on mango in Réunion

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In Réunion, fruit flies (FF) (Diptera: Tephritidae) are major mango pests. Harvest stage optimization and prophylactic elimination of early infestation sources were assessed from 2015-2020, on "Cogshall" mango cultivar, both before and after detection of the invasive oriental FF Bactrocera dorsalis in the island, in 2017. From 2015-2017, fruits were mainly infested by Bactrocera zonata (92%), followed by Ceratitis spp, with a mean infestation level of 7.3%. From 2018-2020, they were infested exclusively by B. dorsalis, with a mean infestation level of 20%. Results obtained in 2015-2017 and 2018-2020 under both natural and artificial infestation with both *Bactrocera* spp suggest that harvesting mangoes at an early maturity stage ("green-mature" or very early "yellow-point") is conducive to a low infestation level by FF, without fruit quality being adversely affected. Observations of small mango fruits during early fruit drop (i.e. about 2-4 weeks after fruit set) showed that green growing fruits on the tree were barely infested (0% in 2018, <2% in 2019), whereas those close to abscission and those fallen on the ground sustained heavy infestation rates (means of resp. 16% and 36%). These early dropped small fruits may therefore serve as sources of FF outbreaks in orchards. Infestation of these fruits was lower on a woven plastic cover than on bare soil or resident vegetation-covered soil. Parasitism by micro-wasps was anecdotal at that stage. The compatibility of these new control levers with those earlier identified for the same or other mango pests (e.g. the mango blossom gall midge) is discussed.

Keywords: Bactrocera dorsalis - Bactrocera zonata - Mangifera indica - Early fruit drop - Maturity stage.

Electrophysiological responses of the Mediterranean fruit fly to Cera Trap[®] and its impact on non-target organisms

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The Mediterranean fruit fly *Ceratitis capitata* (Wiedmann) (Diptera: Tephritidae), is one of the most destructive fruit pests worldwide. For several decades, efforts to suppress *C. capitata* populations relayed heavily on the application of bait sprays including toxic insecticides. As alternative to the insecticidal treatments, the use of mass trapping in Integrated Pest Management strategies (IPM) targeting Mediterranean fruit fly has proven to be efficient. However, there has been much debate regarding the potential undesirable impacts of the attractant on non-target organisms.

Cera Trap[®] is a pesticide-free attractant formulation of natural origin, based on a liquid protein mixture obtained by an exclusive method of enzymatic hydrolysis successfully used over the last fifteen years on citrus, pome and stone fruits and tropical and subtropical fruits.

In order to better understand the mode of action of this lure, here we applied gas chromatography-electroantennography detection (GC-EAD) and coupled GC-mass spectrometry (GC-MS) to attempt the identification of individual physiologically active volatile compounds released by Cera Trap[®]. In addition, the selectivity of Cera Trap[®] was evaluated in field trials assessing the efficacy in capturing target-insects as well as fruit damage.

We identified emitted chemicals belonging to heterocyclic aromatic compounds, aliphatic alcohols, aldehydes, esters, sesquiterpene hydrocarbons, and aromatic alcohols. Efficacy results show that, in all cases, the average of fruit damage did not differ among mass trapping evaluated systems and bait spray treatments, but Cera Trap[®] was found to be the most selective toward non-target insect groups.

Keywords: Mass-trapping - Medfly - Electrophysiology - Selectivity - Beneficial insects.

Integration of novel techniques in Medfly AW-IPM

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Israeli climatic conditions and diverse local variety of agricultural crops and natural vegetation constitute an optimal year round habitat for Medfly (*Ceratitis capitata*). The only way to avoid damage to farmers' produce, without the use of toxic pesticides for the environment, is to use environmentally friendly - Area wide- integrated pest management (AWM-IPM), which consists of a year round «pest control network» of mass trapping in the orchard and targeting spraying reinforcement only at critical times and in hot spots.

Field experiments and accumulated experience through integration of novel techniques includes: Trapping facilities were tested for efficiently and characterized for the operating requirements of each facility to suit the conditions in the pest control interface in Israel where trapping is carried out 10-12 months per year.

Hot spots within the orchard often require intensified insecticide applications in periods of higher host's sensitivity to Medfly, resulting in a several applications until harvesting. Use of an organic sun blocking spray that was developed to prevent sun burns on fruits and dissolve in nature (Decco Shield by Safepack products, Israel) was found to repel Medfly and reduce fruits' infestation, reducing the need for insecticide applications in hot spots.

Another means recently tested and used for hot spots was through precision agriculture (whether in hot spots or plots near houses) by applying baited Spinosad (GF-120). This has allowed for substantial reduction of insecticide applications, and prevented residents' opposition to flying planes over their heads.

Keywords: Ceratitis capitata - Hot spot - Mass trapping - Decco Shield - MedFly.

Invasion

PO-27

Multiple trappings of *Bactrocera dorsalis* complex in France during the 2019 national surveillance survey

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During 2019, a surveillance survey targeting *Bactrocera dorsalis* was implemented in mainland France based on a network of methyl eugenol traps located on crops and sites at risk. It led to the trapping of twelve specimens of the *B. dorsalis* complex, seven in the IIe-de-France region (close to the Rungis international market and Orly airport) and five in the Occitanie region (close to the city of Montpellier and a regional market), with no evidence of any possible establishment.

The barcode region of all intercepted specimens have been sequenced and compared with over 400 barcode sequences representative of the different pathways of entry of the *B. dorsalis* complex into France. Four different COI haplotypes were detected among the twelve intercepted specimens. These findings therefore appear to be linked, at least in part, to repeated introductions of *B. dorsalis* complex through various pathways of entry.

Keywords: Bactrocera dorsalis - Invasive species - Interception - Male lure traps - France.

Traps and attractants

PO-28

Evaluation of mass trapping systems for early seasonal management of *Ceratitis capitata* populations

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Mass trapping is considered an environmentally safe alternative to insecticide application for the management of the Mediterranean fruit fly. However, the performance of most mass trapping systems have not been tested at different times of the season. The current study explored (in the frameworks of the Horizon 2020 "818184 FF-IPM" project) the attractiveness of five mass trapping systems during spring (early season) and summer (late season) under semi-field conditions. For this purpose, we used the ready-to-use Decis trap with its own attractant, and the McPhail and Tephri traps baited either with Biolure or Biodelear. Traps were placed individually in five field cages (2.9m dm x 2m height) housing one potted citrus three or olive tree each. On a test day, 100 medfly adults (50 females and 50 males) were released in each field cage. Trap captures were recorded at hourly intervals (8-9 records/replication). The mean daily temperature ranged from 11°C to 21.9°C and from 26.4°C to 33.5°C during spring and summer trials, respectively. Our results revealed that Tephri trap baited with Biolure was the most effective, followed by the Tephri trap baited with Biodelear, regardless of the season. Capture rates were significantly less in Decis trap. Our result provide useful data regarding the use of mass trapping systems for early season management of the populations of the Mediterranean fruit fly.

Keywords: attractiveness - captures - field cages - OFF-Season detection - traps.

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Monitoring studies to control *Drosophila suzukii* in berries to evaluate bait efficiency for the best pest control

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The spotted wing drosophila, *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae) is an invasive pest that has spread around the world over the last years. This fruit fly has become a major pest for wild and cultivated berry crops in Europe and America. In the area of southern of Spain, the largest producer of European berries, this invasive pest has become a problem and so it has in middle and southeastern Europe. This quickly pest's growth needs an exhaustive fruit fly monitoring in order to adapt the best pest control strategy. The capture of females, which is the reproductive agent, is a good indicator of control and contributes significantly to the interruption of the reproductive cycle of the pest as well as reduces some fruit damage.

Suzukii Trap[®] is a pesticide-free attractant formulation of natural origin, made up of organic acids and peptides obtained by an exclusive method of enzymatic hydrolysis with a strong power of attraction. In order to obtain good monitoring results, it's important to know the effectiveness of the products and taking into account geographical region, its specificity as well as the pest pression of D. *suzukii*. The effectiveness of Suzukii Trap[®] was evaluated in field trials assessing the number of captures differentiating between males and females *D. suzukii* flies per trap. In comparison with other reference bait traps, Suzukii Trap[®] reached higher catches of *Drosophila suzukii* with a higher percentage of females.

Keywords: Monitoring - Drosophila suzukii - Suzukii Trap - Berries - Traps.

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Detection and monitoring of fruit flies (Diptera:tephritidae) in Centeral Sudan

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Trapping program, using McPhail traps baited with male attractants (methyl eugenol, Terpinyl acetate, Cue lure and Trimedlure), was conducted over 48 weeks from June 2009 to May 2010. Morphological identification revealed the presence of *Bactrocera dorsalis, Zeugodacus cucurbitae, Ceratitis cosyra, C. capitata* and *C.quinaria* as a first record of this species in the Sudan. Two species *Dacus ciliatus* and *D.punctatifrons* were only detected in Sennar State, as it is the first record for the latter species to be reported from Sudan where 104 specimeins were caught using Cuelure. Population of *C.capitata* and *C.quinaria* was very low in the two states, (12 and 118 specimens over the trapping period for *C.capitata*, and 146 and 34 *C.quinaria* in Gezira and Sennar State respectively). Generally the population of this species was higher in Gezira (total number of 29514/trap than in Sennar (4778/ trap). *B. dorsalis* proved to be the dominant fruit fly species in Gezira State representing 98.4% of fruit fly composition(caught using methyl eugenol) replacing the indigenous species *C.cosyra* which now represents only 0.03% of fruit fly composition. Results showed that *Z.cucurbitae* was the most abundant species in Sennar State representing 58% of fruit fly composition followed by *C.cosyra* and *B. dorsalis* with a percentage of 20.9 and 20.5 respectively.

Keywords: : Fruit - Fly - Male - Attractant - Biodiversity-Sudan.

Traps and attractants

PO-31

The Fruit Fly Protect project and its actions regarding the essay of different traps and attractants against *Ceratitis capitata* Wied. in Azores

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The Mediterranean fly (*Ceratis capitata* Wiedemann) (Diptera: Tephritidae is one of the most important pests for fruit and vegetable production because of its ability to cause economic damage by causing serious damage to products and to disperse and adapt to new environments. This study aimed to compare different traps, namely Cera Trap and Tephri Trap, both with attractive food attractant in three different islands: Terceira, S. Miguel and S. Jorge in Azores. In 2018, according to the catches of adults obtained in the different traps the Cera Trap proved to be more efficient in both parishes of the island of S. Miguel and also in S. Jorge, showing that it is the most suitable for monitoring and also a good candidate to be used in the control of C. capitate adults. On Terceira island, it was the Tephri Trap that recorded the largest catch of adults. In 2019, the Tephri Trap Econex Trypack trap was the one that proved to be more efficient than Cera Trap in both parishes of São Miguel Island. In 2020, the Tephri Trap trap with Tripack. It can be concluded that the most effective trap in the capture of adults of *C. capitata*, was Ceratrap when population densities present are high and is, therefore, a good bet to be used to control this pest. In the presence of low densities, TephriTrap with the attractive food Tripack revealed to record higher catches with very positive results.

Keywords: Mediterranean fly - Traps - CeraTrap - Tephri Trap - Azores.

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The Fruit Fly Protect project and its actions regarding the essay of different traps and attractants against *Drosophila susukii* (Matsumura) in Azores

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Drosophila suzukii (Matsumura) (Diptera: Drosophilidae) is a pest with a huge dispersion worldwide, is an insect responsible for fruit damage on many fruit hosts of economic importance such as strawberry, blueberry, raspberry, cherry, plum, peach and apricot, and may also affect grape, fig and kiwi. *D. susukii* started to have a great economic impact and because of that its monitoring and control are very important.

The objective of this work was to evaluate a set of traps and baits to find which one is the most effective in the adult's capture and control and possible to be efficient and can be used in the monitoring of this pest.

This study assess the efficiency of three traps and their lures: adapted water bottle with red wine vinegar, Drosotrap[®] and Suzukii Trap[®], in three islands of the Azores Region: São Miguel, Terceira and São Jorge, for the last three years: from 2018 to 2020.

After an analysis of the data obtained in the filed in the three different islands analysed it was possible to conclude regarding the effectiveness of all the tested traps in all the islands that the adapted water bottle trap with vinegar bait was the trap that registered the greatest efficiency with the greater amount of adult captures.

Keywords: traps - lures - strawberry - spotted-wing-drosophila - Azores.

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Is mating disruption a feasible method to control Bactrocera oleae?

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Development of environmentally friendly control methods against the olive fruit fly, *Bactrocera oleae* (Rossi) (Diptera: Tephritidae) is required. Techniques based on the use of semiochemicals, such as mating disruption, have been successfully employed against many lepidopteran pests but its use to control other insect orders, including Diptera, is still under evaluation.

Females of the olive fruit fly are known to produce a sex pheromone, 1,7-dioxaspiro[5.5]undecane (olean). Previous studies demonstrated that the attraction of *B. oleae* males to the pheromone source was reduced by releasing olean over a certain level (~1.28 mg/day), suggesting that olive fruit flies are not able to find the source of olean when its concentration was over this level, which could be a basis for mating disruption. The aim of this work was to study which pheromone concentration is required and the most efficient way to deliver it to reach control of the olive fruit fly by mating disruption.

Results showed that the quantity of pheromone required to reach male catch disruption was over 10 g per ha and month. A disruption in trap location was obtained at this dose, however fruit damage at harvest was over acceptable levels for commercial olive production. Probably, the long lifespan of the males of this species, together with its high dispersal and search capacity, make this pest not a suitable candidate for applying the mating disruption technique. However, we have found that its application with high pheromone doses has allowed to reduce the population of the species.

Keywords: Bactrocera oleae - Mating disruption - Pheromone - IPM - Olive fruit fly.

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Traps and attractants

PO-35

The effectiveness of locally produced protein bait improved with papain in capturing fruit flies of mango

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Fruit flies adversely affected the fruit industry in Nigeria, especially small holders who cannot afford the cost of imported insect control inputs. Consequently, local alternatives were developed to benefit these farmers. Locally made protein bait from autolysed brewery waste (BW) to which different concentrations of crude papain were separately added in local traps was tested. The treatments included: X1 = 188.5 ml BW + 11.5ml papain mixed in 1300ml of water ; X2 = 200 ml BW in 1300ml of water ; X3 = 191 ml BW + 9.0 ml papain in 1300ml of water. One pellet of Torula yeast in 200ml of water (T0) served as the check. A 7 ha orchard planted to Tommy Atkin mango variety was partitioned into 3 blocks. The 4 different baits at 300ml/local traps were allotted randomly to mango trees 50 m apart in each block. The baits were replaced every 7 days after removal of trapped insects. Weekly observations showed that captured fruit flies ranged from mean of 1.7 - 7.6 flies/trap/day out of which 95% were females. The species collected included *Bactrocera dorsalis, Ceratitis cosyra, C. silvestri* and *C. dittissima* with a dominance of *B. dorsalis* (over 90%). There was no significant difference between the number of fruit flies attracted by T0 compared to X1. However, the numbers captured by T0 and X1 were significantly higher than those by X2 and X3. The result showed that BW enhanced with papain was as effective as Torula[®] in attracting different fruit fly species.

Keywords: Bactrocera dorsalis - Brewery waste - Ceratitis cosyra - Papain - Protein bait.

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Current status on spreading of Ceratitis capitata in Romania

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As a result of climate changes as well as intensive human mobility and commerce, *Ceratitis capitata* Wiedemann (Diptera: Tephritidae) has spread from one country to another, reaching Romania in 2007. Since 2013, an early detection program for this started within the framework of three TC regional projects RER5018/RER5020/RER5021, under the coordination of IAEA Vienna and one project 2016-F-236 under Euphresco. Adults were captured using Tephri-Trap® Biolure® baited with ammonium acetate, trimethylamine and putrescine in individual dispensers or Unipack[™], Tephri-Trap® baited with Trimedlure, Jackson traps baited with Methyl Eugenol or Trimedlure. The traps were placed in orchards and in backyards, botanical gardens and experimental fields containing mixed host species for fruit fly such as sour and sweet cherry, apricot, peach, plum, apple or exotic fruit species such as Chinese date, kaki, persimmon and figs, in areas in Romania.

Collecting data from 2013 to 2019, annually confirmed the presence of *C. capitata* in traps on apricot, peach, plum, apple, fig and Chinese date in West, South and South-Eastern Romania with a low (between 1 and 6 specimens/trap/site) and sporadic population. No specimen was found in traps on sweet and sour cherry trees. A higher number of adults was in the traps on Chinese date trees from the experimental field of exotic fruit species of USAMV Bucharest. The total annual captures from this site were between 2 and 202 flies. Based on the dynamics of captures on Chinese date, it can be concluded that medfly develops one generation per year in Bucharest area.

Keywords: Medfly - Spreading - Romania.

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Recent records of *Ceratitis* sp. and *Bactrocera* spp. (Tephritidae, Diptera) in Austria

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While only few native fruit fly species (Diptera: Tephritidae) are relevant for agriculture in Austria so far, high numbers of tephritid interceptions at the EU entry points and especially the finding of one *Bactrocera zonata* specimen in a trap in Vienna in 2011 encouraged increasing survey activities – focused on certain *Ceratitis* and *Bactrocera* species - in Austria during the last years.

The nationwide activities, with special focus on Vienna, started in 2016 with 17 sampling sites and were increased to 41 sites in 2019. Tephritrap type traps (Maxitraps^{*}) charged with different parapheromones (Trimedlure or Methyl eugenol) were placed in orchards with peach or other host plants in different Austrian regions as well as in allotments or alternative sites of the city of Vienna, mainly in vicinity to market areas. During the main fruiting season (May/June to September/October) traps were emptied in fortnightly intervals. The caught tephritids were identified on morphological basis. Molecular analyses (including barcoding and sequencing) were used for the caught *Bactrocera* specimens to support identification and obtain information on the potential origin.

Several hundred specimens of *Ceratitis capitata* were caught in Vienna with catches in each year, and some single catches were also recorded from other Austrian regions. Notably, single specimens of three different *Bactrocera* species were caught in the city of Vienna, too. Next to *Bactrocera zonata*, also *Bactrocera dorsalis* s.l. and *B. kandiensis* was trapped.

Detailed results are presented and discussed.

Keywords: Survey - Detection - Trap - Bactrocera - Ceratitis.

Biological and conventionnal control

Parasitic fitness of a strain of *Diachasmimorpha longicaudata* reared on irradiated larvae of a Vienna-8 strain of *Ceratitis capitata*

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Diachasmimorpha longicaudata (Ashmead) (Hymenoptera: Braconidae) is an Asian-native larvopupal endoparasitoid of fruit flies (Diptera: Tephritidae). It is used worldwide for the biological control of fruit fly species.

In the Valencian Community (Spanish eastern coast) it was imported from Mexico in 2006 to be studied as a potential biological control agent of the medfly, *Ceratitis capitata*, which is one of the most important pests on fruit trees in Spain. To complement the current management of the pest by the Sterile Insect Technique (SIT), mass rearing of the parasitoid using irradiated larvae of a Vienna-8 strain of the medfly was started by the company TRAGSA.

The aim of this work is to determine the potential loss of the fitness of the parasitoid after several generations of mass rearing.

The bioassays were performed analyzing different fitness-related parameters: percentage of parasitism, fecundity, percentage of parasitized pupae and percentage of superparasitized pupae. Two strains of the parasitoid were compared: a laboratory strain which had been reared on wild larvae for more than 50 generations and the TRAGSA mass reared strain. Moreover, the two types of host larvae were analyzed as they could potentially affect adult parasitic fitness.

Results show that adults from the mass reared strain have not lost parasitic fitness after 14 generations reared on Vienna-8 larvae. In contrast, irradiated Vienna-8 larvae show less suitability to both parasitoid strains. We can conclude that the mass reared parasitoids are suitable to be released in the field for the biological control of the medfly.

Keywords: Mediterranean fruit fly - Parasitoid - Mass rearing - Biological control.

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TEAM 2020 - Posters

PO-42

Biocontrol of Drosophila suzukii by two fatty acids

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Olfaction is a crucial sense for insects to detect food, seek partners or escape dangers.

Volatile molecules are mainly perceived through insects' antenna. Odors bind to specific olfactory receptors located in sensilla. Olfactory sensory neurons then synapse on corresponding specific glomeruli of the antennal lobe, the primary olfaction center. This olfactory information is processed in higher centers to trigger a behavioral response.

Understanding how odors can influence insect behavior is fundamental in order to protect cultures from pests.

In this work, two volatile fatty acids are shown to modify significantly *Drosophila suzukii* courtship and copulation at increasing concentrations, and even to induce a reversible anesthesia.

These two acids are non-toxic, and could be used to limit the spread and damages caused by *Dro-sophila suzukii*. Their use offers a solution to protect berry crops and cherries in an environmental-friendly manner by providing a non-killing technology suitable to preserve biodiversity. Patent N° EP19306102.

Keywords: Olfaction - Drosophila - Volatile Fatty Acid - Copulation.

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Use of two odorants to control Bactrocera oleae and Ceratitis capitata

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Many insects are considered as pests because of the damage they cause to cultures. Growers and our society are waiting for environmentally safe strategies to prevent insect damages, without arming the environment and the biodiversity.

Recently we discovered an innovative solution using some odorant molecules to control *Drosophila suzukii* behavior (see summary/poster entitled « Biocontrol of *Drosophila suzukii* by odorant molecules », this meeting).

Using this knowledge we started to investigate the possibility to apply this strategy to *Bactrocera oleae* (olive fruit fly) and *Ceratitis capitata* (Mediterranean fruit fly) to modify their social behavior. This new technology, which is protected by the patent n° EP19306102, could be particularly interesting to avoid infestation of fruits by limiting egg laying and population propagation.

These compounds are non-toxic and could be used to control insects' threats while respecting the environment.

Reproductive effort of the marula fly, *Ceratitis cosyra* (Walker) (Diptera: Tephritidae)

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The marula fly, Ceratitis cosyra (Walker) (Diptera: Tephritidae), is an Afrotropical species that places considerable strain on the production of mango and other fruits. The adults are long-lived and the native host fruits are highly seasonal, which may have led to the evolution of characteristic patterns of reproductive effort. We determined mating propensity, copula duration and sperm storage as measures of reproductive effort in C. cosyra. Sexually mature virgin females (N=329) were placed in individual cages and offered a virgin male of peak reproductive age. Males were introduced into the cages during mid-afternoon and pairs were observed until dawn. Mating occurrence and the time of mating was recorded continuously until the end of dusk, after which pairs were inspected every thirty minutes to note the time that copulation ended. Males were removed at dawn and frozen for measurement of body size, and the spermathecae of 10 random females were dissected to detect the presence and number of stored sperm. We observed a mating propensity of 0.76, which was consistent with a previously recorded mating propensity of 0.73 for C. cosyra¹. On average, the copula duration for C. cosyra was 416.899 ± 11.041 minutes long. To our knowledge, this copula duration far exceeds records from any other tephritid (where males and females were intact), and is similar only to that of Bactrocera tryoni pairs in which female control of copula duration had been removed by decapitation². These results will form the basis for further study on remating inhibition in this species.

Keywords: Copula Duration - Mating Propensity - Reproduction.

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F³ FRUIT FLY FREE: Establishment and maintenance of fruit production areas free and under low prevalence of fruit fly pests in southern Africa

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The Standards and Trade Development Facility (STDF) supports developing countries in building capacity to implement international sanitary and phytosanitary standards, guidelines and recommendations. The STDF approved funding for the Fruit Fly Free project which aims at developing a regionally harmonised framework for development, implementation and recognition of Pest Free Areas (PFA) and Areas of Low Pest Prevalence (ALPP) for regulated fruit fly pests of commercial fruit commodities in southern Africa (i.e. South Africa and Mozambique). The framework will follow guidelines provided in the relevant International Standards for Phytosanitary Measures of the IPPC. The project is a collaboration between different research institutions and government departments from South Africa, Mozambique and Belgium. The target fruit fly pests in the project are *Bactrocera dorsalis, Ceratitis capitata* and *Zeugodacus cucurbitae*.

The following outputs are expected to be achieved:

Established PFA areas in South Africa and Mozambique for target fruit fly species

Scientifically based evidence for specified low fruit fly prevalence levels for target fruit fly pests Established ALPP areas in South Africa and Mozambique for target fruit fly species

Operational database platform for determination of fruit fly status in different regions in South Africa and Mozambique

Identification protocol and service for rapid and unambiguous recognition of target fruit fly pests and related taxa

Financial model for maintenance of PFA and ALPP for target fruit fly pests

The project is coordinated by the Agricultural Research Council of South Africa and will start at the last quarter of 2020 and will run for three consecutive years.

Keywords: Tephritidae - Pest Free Areas - ISPM - Low Pest Prevalence.

Fruit infestation of Drosophila suzukii by fast immunological detection

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Spotted Wing Drosophila SWD (*Drosophila suzukii*) is a serious pest in Europe attacking many softskinned crops such as several berry species and grapevine. SWD is an invasive species arriving Europe in 2008. In contrast to most other Drosophila species, SWD deposits its eggs with the serrated ovipositor into mature, intact, and undamaged fruits. Larvae develop within the fruit that collapse within days. Before collapse the infestation is hardly seen. This may lead to infested fruits that collapse in the shops or after being sold to consumers. Today, farmers may test for infestation by incubation for 48h of the fruits followed by a treatment with saltwater. Larvae escape the fruits and can be counted on the water surface. A more efficient and accurate detection of fruit infestation is currently not available. We aim at developing an antibody-based detection system allowing to rapidly analyze a high number of fruit samples for potential infestation with eggs and larvae of SWD. Some 7 000 potential target proteins have been selected from Casas-Vila (2018) for *in silico* analysis of the expression profiles. The proteins most stably expressed during embryo, larvae, and pupae stages have been selected and used as targets for ELISA and lateral flow device.

Keywords: Pest monitoring - Agriculture - Fruit infestation - Berry crops.

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The Cuarentagri project and its actions regarding the creation of a phytossanitary alert network system on agricultural production, in Azores

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The execution of this Cuarentagri project aims to recognize the pests that may affect the different regions that form the study areas (Azores, Madeira, Canary Islands, Cape Verde and Senegal). These Regions and Countries have a biodiversity not comparable to that of the continental European territory and particular climatic conditions that allow the cultivation of vegetables not present in the rest of Europe but that are affected by different harmful organisms (arthropods and diseases) In short, the main objective of this project is to avoid / reduce the establishment of new harmful organisms in the different areas under study, promoting better training of technicians competent in the matter and information to the sector and citizens in general.

It is important to know which harmful organisms are most likely to be introduced in the Region and to train technicians who deal with these problems in risk analysis On the other hand, as the main pests of our crops are known, it is intended to establish monitoring devices in those crops that allow knowing their evolution and allow the prediction of their appearance and create a warning system. Information and awareness-raising activities for competent technicians in the field and in the plant protection sector will also be developed.

The project will be developed in three Azores islands: Terceira, S. Miguel and S. Jorge. In the first phase several traps were installed to identify and monitor these pests in the main crops: banana, olive, pasture, potato, strawberry, citrus and apple.

Keywords: Alert network - Pests - Azores - Monitoring - Traps.

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Drosophila suzukii adult phenology and fruit infestation levels in coastal and mainland sweet cherry orchards of Greece

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Drosophila suzukii Matsumura (Diptera: Drosophilidae) has invaded and established in Europe during the last decade. However, little is known regarding its population dynamics in coastal areas of the southern Mediterranean countries. Using adult trapping and fruit sampling, we studied the adult phenology of D. suzukii in coastal and mainland (semi-highland) cherry orchards of Greece, from 2018 to 2020. Adults were captured in traps baited with apple cider vinegar, placed in conventional and unmanaged sweet-cherry orchards, and in neighboring wild growing hosts. Sampling of sweetcherry fruit to assess infestation levels was conducted from early and late-ripening cherry cultivars in both areas. Adults were captured throughout the year in the coastal area with two peaks registered in spring and late-autumn. Captures were nearly zero during the hot summer months. Flight activity exhibited only one peak in autumn at the mainland area, and seized during winter and spring. Captures in wild hosts were lower during the sweet-cherry ripening period than later in the season. Higher sweet-cherry infestation levels were recorded in the coastal than in the mainland area and in unmanaged than in commercial orchards. Both early and late-ripening cultivars were highly susceptible to D. suzukii infestation in the coastal area. Infestation rates were higher in late-ripening cultivars than in early-ripening ones in the mainland area. We conclude that D. suzukii has well adapted to the Mediterranean climate of Greece, and is able to progressively exploit several crops and wild hosts of mainland and coastal areas.

Keywords: Spotted wing Drosophila - Invasive pest - Population dynamics - Flight activity - Sweetcherry susceptibility.

Bactrocera dorsalis an invasive fruit fly species

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The Oriental fruit fly, *Bactrocera dorsalis* was first detected in Mauritius in 1996 and then declared eradicated in 1999. A second interception was made in 2013 and it was eradicated. The insect was recorded a third time in 2015 and it spread to the whole island. Sample of fruits have been collected regularly, weighed and incubated in the laboratory to determine the infestation levels. Results showed that *B. dorsalis* has gradually displaced Bactrocera zonata, *Ceratitis rosa* and *C. quilici* in fruits.

Keywords: Surveillance - Fruit fly - Hosts.



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