PROJECT DELIVERABLE REPORT

Deliverable 8.8: Recommendations to policy makers on advantages and feasibility of the new FF management paradigm

Fruit Flies In-silico Prevention & Management

FF•IPM

Project Title:

In-silico boosted, pest prevention and off-season focused IPM against new and emerging fruit flies ('OFF-Season' FF-IPM)

SFS-2018-2

"This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 818184– H2020-SFS-2018-2

Document Information

Grant Agreement Number	818184	Acronym	FF-IPM
Full Title	In-silico boosted, pest prevention and off-season focused IPM against new and emerging fruit flies ('OFF-Season' FF-IPM)		
Topic	SFS-05-2018-2019-2020 New and emerging risks to plant health		
Funding scheme	RIA - Research and Innovation action		
Start Date	1st September 2019	**Duration**	54months
Project URL	http://fruitflies-ipm.eu/		
EU Project Officer	George PREDOIU		
Project Coordinator	UNIVERSITY OF THESSALY - UTH		

Deliverable	**D8.8 - Recommendations to policy makers on advantages and feasibility of the new FF management paradigm**			
Work Package	WP8 – Communication and dissemination			
Date of Delivery	**Contractual**	M54	**Actual**	M54
Nature	R - Report	**Dissemination Level**	PUBLIC	
Lead Beneficiary	AGES			
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Reviewer(s):	FF-IPM Consortium			
Keywords	FF-IPM developed tools & approaches, advantages, feasibility, implementation, obstacle identification, recommendations to policy and stakeholders			

Revision History

Version	Date	Responsible	Description/Remarks/Reason for changes
0.10	12/01/2023	AGES	Deliverable structure set-up (S. Bluemel)
0.20	11/12/2023	AGES	Updated structure & 1st draft contents including mapping results (S. Bluemel)
0.30	29/02/2023	ISCTE	2nd draft contents including questionnaire results (A. Larcher Carvalho)
0.30	01/03/2024	UTH	Revision of the 2nd draft (N. Papadopoulos)
0.40	07/03/2024	AGES, ISCTE	Final Draft concluded (S. Bluemel and A. Larcher Carvalho)
0.50	08/03/2024	RMCA	Final draft reviewed (M. de Meyer)
0.60	09/03/2024	UTH	Final draft reviewed (N. Papadopoulos)
0.70	11/03/2024	AGES, ISCTE	Revised final draft submitted (S. Bluemel, A. Larcher)
0.80	12/03/2024	RMCA, UTH	Final check of the deliverbale (M. De Meyer, N. Papadopoulos)
0.90	15/03/2024	EB	Final draft approved (FF-IPM)
1	20/03/2024	UTH	Deliverable uploaded (G. Pahlitzanakis)

1 Summary

Deliverable 8.8 presents recommendations to policy and decision makers at national and EU level on advantages and feasibility of novel tools which were developed within the framework of the FF-IPM project, including rapid and unambiguous detection and identification tools, new prediction tools (FF DSS-Alert system), and a new fruit fly (FF) management paradigm shifting towards an "OFF-Season" IPM strategy and Virtual-Farm DSS. The deliverable includes the description of the applied methodology to identify potential implementation obstacles with regard to pertinent standards and regulations and relevant stakeholders. Additionally, communication approaches to inform top target groups about the novel and improved tools, strategies and approaches regarding FF interception detection and management are reported. Finally, recommendations to policy makers are formulated on how to facilitate the adoption of FF-IPM management tools and strategies.

2 Introduction

2.1 Purpose and Scope

The main objective of D8.8 is to provide recommendations to policy makers regarding the adoption of the innovative tools and strategies developed by the FF-IPM project to address targeted invasive and emerging fruit flies (FF) in Europe. To achieve this, the research involved conducting a mapping of stakeholders to identify those that may use the tools/strategies or influence their adoptability. It also involved the mapping of standards and regulations with an impact on the adoptability of FF-IPM tools and strategies. In addition, it involved gathering, through several methods, the perceptions of stakeholders about the advantages and adoptability of each of the fruit fly management tools and strategies. Finally, based on the above analysis, recommendations were formulated for policymakers to facilitate the adoption of the FF-IPM developed novel tools and strategies to address invasive FF. The target species of the FF-IPM project are the oriental fruit fly (*Bactrocera dorsalis*), the peach fruit fly (*Bactrocera zonata*) and the Mediterranean fruit fly, (medfly; *Ceratitis capitata*). Both *Bactrocera* species are frequently intercepted and recently detected in Europe, while *C. capitata* emerges as a new pest in more temperate areas of Europe in recent years.

The deliverable is organised in the following sections:

Methodology: This section outlines the methods employed to map the stakeholders and the regulatory landscape affecting the adoption of FF-IPM tools and strategies. It also describes the methods to gather the perceptions of stakeholders regarding benefits, barriers to adoption and strategies to facilitate adoption of the various tools and approaches.

Results: This section presents the findings from the stakeholder and regulatory mapping exercises, offering insights into the potential for integrating FF-IPM tools and strategies into existing plant health and pest management frameworks. It also presents the perceptions of stakeholders including strengths, shortcomings and suggestions for adoption of each FF-IM tool and strategy.

Communication with High-Level Policy and Decision Makers: This section describes the project's efforts to engage with high level European policymakers and decision-makers and present some of the outcomes of the conversations held. Effective communication is essential in bridging the gap between scientific research and policy action.

Tailored Briefing Materials: Describes the creation of communication materials designed to disseminate the project's innovations and solutions to a diverse range of stakeholders, with the aim of making the solutions actionable.

Policy Recommendations: Presents recommendations for policymakers, outlining actions to facilitate the adoption of the FF-IPM strategies.

2.2 FF-IPM strategies and tools

The FF-IPM project responds to several current and imminent challenges for the control of emerging and new frugivorous FF and the production of their host plants in Europe and beyond, based on three pillars:

- the pressure to reduce the use of synthetic, chemical pesticides and their declining availability,
- the necessity to address the introduction and spread of invasive fruit fly pests and the expected range expansion of established species due to changing climatic conditions,
- the necessity to reduce growing risks of trade barriers for imports as well as exports.

The FF-IPM project thus contributes to reduce the economic pressure caused by three highly polyphagous fruit fly species (*B. dorsalis, B. zonata, C. capitata*) to farmers and fresh fruit production industry in Europe and beyond, as well as to a more stable environment for traders. It also aims to improve overall food security and food safety for consumers and to reduce risks for the human and natural environment.

The answers and knowledge-based support provided by the project will have impacts on plant health planning and policies on international, national, regional and farm level.

The Off-Season paradigm to manage fruit fly population in European farms (see FF-IPM deliverables D6.3 and 6.4) as well the effort to address alien invasive, and new emerging FF require interventions on various levels.

The first pillar is risk analysis, as exemplified by the DSS-Alert system (see FF-IPM deliverables D5.3, 5.4, and 5.5) which models climate related risks on all levels, from the European level to the farm level.

The second pillar is interception (D3.6), early detection (D3.1) and identification of invasive FF (see FF-IPM deliverables D3.1, D3.3, 3.4 and 3.5). This applies mainly to invasive FF but also to FF expanding their current geographic distribution emerging as new pest in more temperate, cooler climate zones.

The third pillar is the reduction of the use of synthetic, chemical pesticides by adopting Off-Season and the newly developed On-Season FF-IPM strategies and environmentally and biodiversity friendly methods for fruit crop protection (see FF-IPM deliverables D4.1 and 4.5). Combinations of the novel methods can also be applied in organic farming.

In most temperate regions in Europe, the seasonal phenology of medfly populations demonstrates no detection for several months during winter and spring, and increased population densities in summer with peaks occurring relatively late (autumn), coinciding with the main fruiting season in summer or early autumn, leaving early ripening fruit crops relatively unaffected. Although in mild climates female activity begins in spring, well before the main fruiting season, the overwintering population usually occurs in extremely low densities, which are rarely revealed by ordinary monitoring and are therefore not considered a problem.

Monitoring medfly population is considered the cornerstone of the classic IPM paradigm, and farmers are typically advised to start medfly control when the pest consistently appears in monitoring traps and reaches the conventional economic threshold level. But typical farmer-conducted monitoring with a limited number of traps is not sensitive enough to generate reliable empirical information on the early stages of seasonal population growth. Usually, the farmer is warned too late, which necessitates intense use of immediate-acting pesticides to reduce or prevent damage to the fruit.

The FF-IPM project recommends a shift in the medfly management paradigm towards preventive early 'Off-Season' approach to target the overwintering medfly population on the earliest fruit before it builds up early in summer. The Off-Season approach is intended to complement the standard seasonal management to optimise the overall IPM strategy. It is therefore a combination of Off-Season and On-Season with eco-friendly methods that are applied in a strategic way following IPM scenarios that are generated by the Pest on Farm platform.

Table 1 identifies the novel management tools and approaches developed and improved in the framework of the FF-IPM project to support (a) prevention, interception and detection efforts for the target invasive FF and (b) the shift to a combined Off-Season/On-Season strategy for an optimised fruit fly IPM production.

Table 1. Novel and improved FF-IPM developed tools and approaches to support the Off-season/On-season strategy.

Management approach	Management Tool	Product short description
Prevention & early detection of invasive/emerging FF	Electronic keys for adults & larvae ID	Electronic multi-entry keys based on morphological characters for adults & larval instars (mobile application)
	Molecular ID LAMP	Rapid-Molecular-Pest-ID tools and protocols for intercepted FF
Early detection, warning & forecasting	**"e-Trap"** Species specific automated e-Trap system	Species specific automated traps with micro-camera-type sensor, providing high-resolution pictures of the trapped specimen
	Automated pan European alert systems	Trapping data and alert signal of each trapping event can be shared worldwide
	DSS-Alert Dynamic (real-time) pan-European forecast toolbox,	Surveillance and forecasting system for efficient surveillance and inspection for border biosecurity. Generation of European weekly risk maps and real-time FF alerts to inform biosecurity surveillance operators about the timing and location of plant health threats e.g. introduction and establishment risks of *Bactrocera dorsalis* and *Bactrocera zonata*.
Improved Biocontrol and IPM FF management	**In silico models** **DSS-Virtual-**Farm	Locally optimised IPM in fragmented and mosaic agrolandscapes
	Control tools	
	Nematode biocontrol tool	Biocontrol of soil inhabiting stage of FF (larvae) with commercially available nematodes
	Ground-dwelling-predator-based biocontrol tool	Biocontrol of soil inhabiting stage of FF (larvae, pupae) using soil cover with *Festuca arundinacea* or straw. Reduces emergence of adult FF
	Entomopathogenic fungi-based biocontrol tool	Biocontrol of soil inhabiting stages of FF (larvae, pupae) with entomopathogenic fungi BCAs
	Lure and Kill	IPM of soil overwintering adults with commercially available lure-and-kill (e.g MagnetMed) and mass trapping (e.g. Decis traps) devices

Most of the mentioned tools were developed to a ready of use level or are in use already. For further details regarding TRL levels achieved for each product see D7.6.

The early detection tools for the morphological and rapid molecular identification of adults and larvae of fruit fly species invasive to Europe or emerging species are already in use.

Also, the Decision Support-Alert system was developed to the level of ready to use products.

The early detection tool for monitoring of (first) occurrences of FF at border entries or exits and in the field, the species-specific automated e-Trap system was developed to a prototype level which could be commercialised in future.

The improved or novel biocontrol tools, such as nematode biocontrol by entomopathogenic nematodes, the ground-dwelling-predator-based biocontrol tool, the entomopathogenic fungi-based biocontrol tool and the Lure and Kill tool were developed to the level of ready to use products but need commercialization.

The automated "e-nose" system for non-destructive tracking of fruit fly infested fruits for rapid interception by recognising specific volatile profiles of the fruit as preventive measure for plant health at border entry points could only be developed to an experimental level.

3 Methodology

3.1 Mapping of standards and regulations affecting adoption of novel FF management tools and strategies.

An exhaustive mapping of standards and regulations relevant to the adoption of FF-IPM developed tools and strategies was conducted. This mapping focused on both international standards, such as those set by the International Plant Protection Convention (ISPM), EU and national regulations, standards and conventions. The objective was to identify the regulatory landscape and how it currently facilitates or restricts the implementation of novel FF management tools and strategies.

Regulations, standards and conventions, which potentially could be affected by relevant project results were mapped by allocating them to four thematic categories and describing in how far they could be affected (table 2) Regarding the geographical extension the mapping of the above-mentioned rules was restricted mainly to Europe and neighbouring areas (EU, EPPO,) and in particular to countries in Europe amongst the FF-IPM partners, which are typical representatives of countries with entry/border countries of the EU, countries with a large production of affected crops and for countries with a high trade volume of concerned crops(fruits).

Additionally, a survey of potential organisations and stakeholders which should be informed about the novel and improved tools and the expected obstacles for their implementation was compiled (table 3). From this survey a list of stakeholders of interest for project products for use in practice from different target groups was composed, based on information from the different partner countries.

3.2 Stakeholders' perceptions about advantages and feasibility of FF-IPM strategies

The perceptions of stakeholders were collected using a variety of methodologies throughout the project. To deepen the discussion about obstacles for adoption and to derive suggestions to facilitate the adoption of the newly developed approaches and tools, various workshops with different stakeholders were held (https://fruitflies-ipm.eu/news-and-events/news-events/; e.g. D5.1, 6.1). The information was completed

by several project meetings with the participation of external stakeholders and member of the advisory board and feedback collected during the field experiments.

3.2.1 Stakeholder meetings

A series of stakeholder meetings were organised by the FF-IPM partners in three countries where the pilot sites were set up, namely Greece (University of Thessaly, Benaki Institute), Italy (University of Molise) and Spain (ANECOOP). The workshops took place from the beginning of the project in 2019 and subsequently in 2020 (see Deliverable 6.1.) and 2022. In these workshops were presented the project concepts and strategies for fruit fly control within the framework of FF-IPM with a focus on the OFF- & ON-Season IPM and in-silico approach to design and optimisation of local IPM. Several meetings were also held to discuss the possibilities and limitations of the alternative FF-IPM strategies with stakeholders at the pilot sites.

The meetings engaged a broad range of actors with complementary knowledge including fruit producers, growers' cooperatives and associations, traders, exporters and other business, advisors, cooperatives and NGOs, public administration, and research. Additional meetings were held to present a portfolio of IPM evaluation scenarios for stakeholder approval and to discuss the feasibility of the alternatives in the field.

FF-IPM stakeholders' meetings were also held in other countries (Croatia, Israel, South Africa). In Split, Croatia several workshops were organized by the FF-IPM consortium partner University of Split, presenting some of the FF-IPM developed tools and services to stakeholders. The tools presented included the DSS-Alert tool and the Early Warning Strategy and it was an opportunity to discuss the benefits and obstacles to adoptions of these FF-IPM strategies.

Workshops were also held in South Africa: (2019, 2023) by the FF-IPM partner, Citrus Research International (CRI). The objective of the workshops was to bring together the National Plant Protection Organisation (NPPO) of South Africa and other stakeholders to understand the challenges they are facing in managing plant health threats from invasive FF and discuss their needs, priorities and recommendations regarding an improved alert and early warning detection system. There were participants from the NPPO of South Africa and from the citrus industry. It was clear that for all the stakeholders present, systems that would be able to (1) forecast pest distribution based on prevailing climate and landscape and (2) inform on pest status, ecology, infestation level and management would improve their decision making.

3.2.2 In-depth Interviews with high level decision makers

Several interviews were conducted by ISCTE with high level decision makers to learn about their perspectives about the strategies and tools developed by FF-IPM and potential envisaged obstacles for the implantation of novel tools and approaches developed in FF-IPM. The interviews were conducted with representatives of EPPO and EU DG SANTE (Directorate-General for Health and Food Safety) as well as the Joint FAO/IAEA division and the with the leading entomologist in the Branch of Biosecurity and Food Safety of New South Wales, Australia.

All the interviews are available in the FF-IPM newsletter: https://fruitflies-ipm.eu/news-and-events/newsletter/).

3.2.3 Online survey

An online survey to collect perceptions of various stakeholders about the FF management tools, was also developed. For each tool and strategy developed by the project, the online questionnaire asked the following questions:

- The advantages of FF-IPM strategies and tools:

- Reflect on the benefits and strengths of the strategies and tools we have developed.

- Potential Barriers:
  - Identify any obstacles or challenges that could hinder their adoption. What are the main concerns or limitations from your viewpoint?
- Strategies to facilitate Adoption and Policy Recommendations:
  - Identify strategies that could enhance the adoption of FF-IPM initiatives in particular specific recommendations for policymakers. These could include proposed measures or policy changes at various levels—be it international (e.g., ISPM, EPPO), within the European Union, or at the national level—that could support the widespread implementation of these strategies.

The questionnaire was supported by an online resource[1] which included a 1-page summary description of each tool prepared by the Consortium partner responsible for its development and links to other complementary documentation.

Additionally, a survey of potential organisations and stakeholders which should be informed about the novel and improved tools and the expected obstacles for their implementation was compiled. From this survey a list of stakeholders of interest for project products for use in practice from different target groups was composed, based on information from the different partner countries.

The questionnaire was sent to key stakeholders that have been engaged in several ways with the project throughout its development.

4 Results

4.1 Mapping of standards and regulations affecting adoption of novel FF management tools and strategies

This section analyses the standards and regulations that may affect adoption of FF-IPM detection and management tools and strategies. The international, EU and national regulations, standards and conventions which were considered to potentially affect the adoption of FF-IPM tools and strategies could be allocated to four thematic categories: (a) plant health (quarantine pests), (b) plant protection (control), (c) environmental/nature protection and (d) telecommunication.

In the category of plant health, four specific and five more general ISPMs (International Standards for Phytosanitary Measures, https://www.ippc.int/en/publications/ including Diagnostic Protocols and Phytosanitary treatments) could affect the adoption with regard to the compliance of developed/novel tools with specific requirements for e.g. surveillance, detection, inspection, prevention, eradication and containment or recommendations for the improvement and/or adaptation of current diagnostic protocol(s), or the suitability of developed tools for consignments after phytosanitary treatments (PTs) according to valid PT protocols (Table 2).

For eight European regional standards, the newly developed FF-IPM tools could provide recommendations for the improvement, and/or adaptation of current inspection measures and diagnostic protocol(s).

Regulatory compliance is explicitly required for the application of inspection measures and diagnostic protocol(s). Thus, the use of the electronic multi-entry keys for the identification of adult FF and 3rd instar

[1] https://padlet.com/GENEPadlet/ff-ipm-fruit-flies-in-silico-prevention-and-management-thvkkdieo8bdq6kb

larvae based on morphological characters or the use of molecular tools in the context of improved prevention and detection should have been validated and ideally be approved ***as recommended diagnostic methods in Europe,*** both in the European Union (EU, https://food.ec.europa.eu/plants/plant-health-and-biosecurity_en) and in the region covered by the European and Mediterranean Plant Protection Organization **(**EPPO, https://www.eppo.int/).

In contrast, several other newly developed tools or products for plant health purposes could be implemented by National Plant Protection Organisations (NPPOs) as additional tools without specification in regulations, such as the species-specific automated e-Trap system for improved monitoring of invasive fruit fly adults as FF-Alert service for early detection and warning.

For the category plant protection one ISPM standard, several EPPO standards and specifically two EU regulations/directives could strongly affect the adoption of FF-IPM-tools and products, especially the authorization and release of biocontrol agents, such as the nematode-based and the entomopathogenic fungi-based biocontrol tools.

The two other developed tools, the lure & kill for Off-season IPM and the ground-dwelling-predator-based biocontrol will not be primarily affected by regulations but need knowledge transfer to advisory service and growers.

Table 2. Survey of international/national standards/regulations potentially be affected (both positive and negative) by novel/improved FF management tools, approaches.

Sector of action	Standard level/Stakeholder	Acronym, title, link	Potentially be affected by/through
Plant health quarantine organisms	International conventions/IPPC	International Plant Protection Convention -->defines ISPMs (International Standards for Phytosanitary Measures, including Diagnostic Protocols and Phytosanitary treatments)	see ISPMs
	IIPC/International standard	ISPM standards (in total 44) specifically No. 26, 27, 28, 29, 30 (plus PTs)	
		ISPM 14 (The use of integrated measures in a systems approach for pest risk management),	general non-compliance of developed/novel tools with requirements (efficacy)
		ISPM 20 (Guidelines for a phytosanitary import regulatory system),	general non-compliance of developed/novel tools with requirements
		ISPM 22 (Requirements for the establishment of areas of low pest prevalence)	non-compliance of developed/novel tools with "specific requirements" e.g. surveillance
		ISPM 23 (Guidelines for inspection),	additional tool for inspection
		ISPM 26; Establishment of pest free areas for FF (Tephritidae)	general non-compliance of developed/novel tools with requirements for surveillance, detection, control
		ISPM 27; Diagnostic protocols for regulated pests DP 29: *Bactrocera dorsalis*,	recommendations for improvement, adaptation of current diagnostic protocol

Sector of action	Standard level/Stakeholder	Acronym, title, link	Potentially be affected by/through
		ISPM 28 Phytosanitary treatments for regulated pests PT 07 (2009): Irradiation treatment for FF of the family Tephritidae (generic) PT 14 (2011)[2]: Irradiation treatment for Ceratitis capitata PT 24-29, 34-36: Cold treatment for Ceratitis capitata in different fruits PT 30: Vapour heat treatment for Ceratitis capitata on Mangifera indica PT 32: Vapour heat treatment for *Bactrocera dorsalis* on Carica papaya	unsuitability of developed tools for consignments after phytosanitary treatments according to PTs
		ISPM 35 (Systems approach for pest risk management of FF (Tephritidae)), including ISPM 30 (Revoked by CPM-13 (2018)) REVOKED. Establishment of areas of low pest prevalence for FF (Tephritidae)	non-compliance of developed/novel tools with "specific requirements" e.g. surveillance
		ISPM 37 (Determination of host status of fruit FF) (Tephritidae)	Support implementation current standard
	Regional standard EPPO	EPPO Standards on Phytosanitary Measures (PMs) [3] PM 7 Series Diagnostic Standards (130 in total) PM 7/104(1) *Ceratitis capitata* PM 7/114(1) *Bactrocera zonata*	recommendations for improvement, adaptation of current diagnostic protocol(s)
		EU-Reference-Laboratory methods (EURL for insects & mites)[4] and recent validation studies for *B. dorsalis, B.zonata*[5]	recommendations for improvement, adaptation of current diagnostic protocols for FF-species
		EPPO Standards on phytosanitary procedures[6] PM 3 Series for Phytosanitary Procedures PM 3/90(1) Inspection of citrus fruits consignments PM 3/92(1) Consignment inspection of fresh fruit and vegetables for FF	recommendations for improvement, adaptation of current inspection measures
	Regional legislation/EU	Regulation (EU) 2016/2031 of the European Parliament of the Council of 26 October 2016 on protective measures against pests of plants, amending Regulations (EU) No 228/2013, (EU) No 652/2014 and (EU) No 1143/2014 of the European Parliament and of the Council and repealing Council Directives 69/464/EEC,	non-compliance of developed tools with specific objectives

[2] https://www.ippc.int/en/publications/625/

[3] https://www.eppo.int/RESOURCES/eppo_standardsEPPO

[4] https://eurl-insects-mites.anses.fr/en/minisite/insects-and-mites/available-identification-methods

[5] Taddei, A., Reisenzein, H., Mouttet, R., Lethmayer, C., Egartner, A., Gottsberger, R. A., Blümel, S., Heiss, C., Pohn, C. & Reynaud, P. (2023): Morphological and molecular identification protocols for Bactrocera dorsalis: a joint validation study. – PhytoFrontiersTM Published Online:24 Mar 2023, https://doi.org/10.1094/PHYTOFR-03-22-0031-FI

[6] https://www.eppo.int/RESOURCES/eppo_standardsEPPO

Sector of action	Standard level/Stakeholder	Acronym, title, link	Potentially be affected by/through
		74/647/EEC, 93/85/EEC, 98/57/EC, 2000/29/EC, 2006/91/EC and 2007/33/EC[7]	
		Commission Implementing Regulation (EU) 2021/2285 of 14 December 2021 amending Implementing Regulation (EU) 2019/2072 as regards the listing of pests, prohibitions and requirements for the introduction into, and movement within, the Union of plants, plant products and other objects, and repealing Decisions 98/109/EC and 2002/757/EC and Implementing Regulations (EU) 2020/885 and (EU) 2020/1292[8]	non-compliance of developed tools with specific objectives
Plant Protection	International standards/IPPC	ISPM 03 (Guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms)	non-compliance of developed tools with standards
	Regional standard/EPPO	EPPO Standards on plant protection products (PPs)[9] PP 1/181 (5) Conduct and reporting of efficacy evaluation trials, including good experimental practice	non-compliance of efficacy trials for developed tools with PP standards
		PP 1 – Efficacy Evaluation of Plant Protection Products, 301/302 Ceratitis capitata	non-compliance of efficacy trials for developed tools with PP standards
	Regional legislation/EC	Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC [10]	submission of dossiers for authorization of (new) BioControl Agents (BCAs) for FF control
		Directive 2009/128/EC of the European Parliament and of the Council establishing a framework for Community action to achieve the sustainable use of pesticides.	non-compliance of developed tools with specific objectives
		EPPO Standards – PM 6 Safe use of biological control [11]	non-compliance of developed tools with standards
Environmental protection	International standards/IPPPC	ISPM 03 (Guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms)	non-compliance of developed tools with standards
	International conventions	Convention on biological diversity https://www.cbd.int/abs	non-compliance of developed tools with specific objectives

[7] , https://eur-lex.europa.eu/eli/reg/2016/2031/oj

[8] https://eur-lex.europa.eu/eli/reg_impl/2021/2285/oj

[9] https://pp1.eppo.int/

[10] https://eur-lex.europa.eu/eli/reg/2009/1107/oj

[11] https://www.eppo.int/RESOURCES/eppo_standards/pm6_biocontrol

4.2 Mapping of stakeholders in fruit fly management in the EU

Fruit fly management involves a diverse array of stakeholders playing different roles in the implementation of pest management strategies. The adoption of FF-IPM strategies and tools rely on a number of stakeholders who have differing roles in pest management. This section analysed who are the key stakeholders in FF-IPM and what is their role in fruit fly management. The objective is to identify which stakeholders would be interested in the tools and who might use them directly, as well as stakeholders who could indirectly influence adoption through regulations and standards.

These stakeholders can be broadly organised into several tiers, as reflecting their direct and indirect involvement and influence on how FF are managed. These stakeholders in the top tiers impact the groups at lower levels. In the context of pest management, and in particular fruit fly management, the hierarchy begins with international agencies and national governments at the top tier, followed by reference laboratories, regional services of the NPPO Quarantine Inspectors, pest management scientists and extension workers in the second tier. The third tier includes private entities, while the fourth tier comprises farmers and farmers associations. The fifth tier consists of consumers, customers, and communities who benefit from (or are affected by) the actions taken by the upper tiers.

The adoption of FF-IPM approaches relies on the combined efforts of stakeholders across these tiers, each contributing to the development, application, and evaluation of fruit fly control measures. Table 3 presents stakeholders and their roles in the management of FF.

Table 3 identifies a range of regulators and standard-setting organizations such as the International Plant Protection Convention (IPPC) and the European and Mediterranean Plant Protection Organization (EPPO), which play a critical role in the adoption and implementation of these tools. Other entities that may influence the adoption of these strategies, such as the International Atomic Energy Agency (IAEA), are also mentioned, underscoring the collaborative effort required to combat fruit fly infestations effectively.

Table 3. Stakeholder and their roles in the management of native and invasive FF in the EU

Tier	Category	Stakeholders	Role in fruit fly management
1	International organizations	FAO	Pest management guidelines Quarantine pest management guidelines/emergency preparedness guidelines for quarantine pests Research on alternatives to pesticides Support for fruit fly management programmes in the field.
1		Joint FAO/IAEA Division	Research on fruit fly detection and management Trapping protocols Costs benefit analysis of area-wide control
1		IPPC (International Plant Protection Convention)	Standard setting: *four specific and five more general ISPMs (International Standards for Phytosanitary Measures, including Diagnostic Protocols and Phytosanitary treatments)*
1	EU level	EC DG SANTE DG agriculture	Phytosanitary legislation/quarantine pests Pest Risk Assessment Pesticide legislation
1		EPPO (European and Mediterranean Protection Organization)	EPPO sets regional standards for phytosanitary measures and plant protection products Conducts pest risk assessments.

Tier	Category	Stakeholders	Role in fruit fly management
			EPPO diagnostic protocols *recommended diagnostic methods in Europe* EPPO procedures for official control Provide sequence data for the EPPO Q-Bank database Develops communication materials (e.g. raising awareness of *B. dorsalis* in Italy)
		European Food Safety Authority (EFSA)	Pest Risk assessment Pest reports for invasive species Pest survey cards
1	National public authorities	Governmental level	Policies and incentives for agriculture Investments in infrastructure and human and social capital Funding of agriculture Subsidies
1		Ministry of the environment	Environmental monitoring
1		Ministry of health	Protect human health and ensure that pesticides do not pose unnecessary risks to individuals or communities.
1		Ministry of agriculture	Funding to agriculture
1		NPPO (National Plant Protection authorities)	Pest risks analysis Elaboration of Action Plans for Invasive FF Monitoring guidelines for quarantine pests Compilation of reports from quarantine pest monitoring Development of systems approach protocols with importer countries MRL (Maximum Residue Level) Monitoring: registration, approval, and monitoring of pesticides to ensure their safety and environmental impact are within acceptable limits. Typically, this is the role of the NPPO, in collaboration with regulatory bodies, ministries of agriculture, health, and the environment, to enforce MRL compliance and conduct regular monitoring and testing of agricultural products.
2		Regional services of the NPPO Quarantine Inspectors	Monitoring FF in the field and at borders
2		Reference laboratories	Fruit fly identification
2		Extension and advisory services	Warnings to farmers Advice on fruit fly management
2	Academia	Academics, pest management scientists	Conduct research on alternative control methods. conduct research and provide valuable insights on the impact of pesticide use on human health and the environment.
3	Private sector	Technical Advisors	Pest management advice
3		Agrochemical companies	Pesticide production and distribution
3		Other pest control companies	Production of beneficials and environmentally friendly control methods
3		Agroindustry associations Industry	Quality control Pest management protocols for exports

Tier	Category	Stakeholders	Role in fruit fly management
3		Plant protection distributors and retailer	Pesticide and control methods distribution and advice
4	Farm level	Farmers	Farmers use pesticides for fruit fly management, leading to higher yields and improved agricultural productivity. They may be exposed to pesticides and need protection and training to use them safely.
4		Farmers associations and cooperatives	Advice on pest control
5	Community level	Consumers and communities	Consume agricultural products: expect safe use of pesticide to ensure their safety
5		NGO (Non Governmental Organization)	Environmental monitoring. These groups advocate for the protection of ecosystems and wildlife, and work to ensure that pesticide use does not harm or negatively impact the environment.

Table 4 presents a comprehensive overview of various tools and strategies developed by FF-IPM the management of FF linking them with the roles of different stakeholders in the adoption of these tools. Primary users of these tools, range from National Plant Protection Organizations (NPPOs) and phytosanitary inspectors to growers and their associations, indicating the broad applicability and relevance of these innovations across different stakeholders in agriculture. Regulators and standard-setting organizations include, as identified in the previous table, the IPPC, and EPPO and the EC, which play a critical role in the adoption and implementation of these tools. The implementation of the FF-IPM tools required the collaboration with these organizations.

Table 4. Overview of FF-IPM Project Tools and Strategies: Users and Roles of Influential Stakeholders

Tools/Strategy	Specific tool		Roles	
		Users	**Regulators/ standard setting**	**Other that may influence adoption**
Detection Tool	**"e-Nose"** for non-destructive tracking of FF infested fruits for rapid interception	NPPO Phytosanitary inspectors	IPPC	IAEA
Detection Tool	**e-Trap**	NPPO	IPPC	IAEA
ID tool	**Electronic keys for adults & larvae ID**	NPP0 border control National Reference Labs	EC, EPPO [12]	IAEA
	Molecular ID LAMP	NPP0 border control	EC, EPPO	IAEA

[12] EPPO and NPPO can provide opinion and advice on the decision protocols

Tools/Strategy	Specific tool		Roles	
		Users	Regulators/ standard setting	Other that may influence adoption
		National Reference Labs		
New Approaches for detection	Automated pan European alert systems	NPPO	EC, EPPO	
In silico models	**DSS-Alert** Dynamic (real-time) pan-European forecast toolbox	NPPO	EC, EPPO	
Control tools	Nematode biocontrol tool	Growers Growers Associations Plant Protection Companies	EC	
	Ground-dwelling-predator-based biocontrol tool	Growers	EC	
	Entomopathogenic fungi-based biocontrol tool	Growers	EC	
	Lure and Kill	Growers	EC	
In silico models	**DSS-Virtual-**Farm	Extension services Technical advisors NPPO Growers Growers Associations	EC	
New Approaches for fruit fly management	In-Silico boosted Off season IPM paradigm	Growers Growers Associations Extension services Technical advisors	EC	

4.3 Stakeholder perceptions regarding FF-IPM strategies and tools

This section presents the perceptions of stakeholders regarding the benefits and strengths of the strategies and tools developed by FF-IPM as well as obstacles or challenges that could hinder their adoption from their viewpoint. It summarises the findings from workshops, high level meeting, field work and an online questionnaire.

4.3.1 Strategies and tools for fruit fly early detection

Pest detection: E-trap

Description:

A MacPhail type trap and a Delta e-traps equipped with automated algorithms to accurately identify captured, invasive FF of relevance to EU.

Both traps are fully functional, and the McPhail type has already been adopted to detected invasive FF at ports receiving commercial shipments of fresh fruits (D3.1).

Benefits and strengths

- Improved monitoring of adult invasive FF with traps baited with specific lures to attract species of interest and avoid a negative impact on the natural habitat and fauna.
- Useful for rapid assessment of population changes, flare-ups, incursion points.
- Real time detection of invasive pests, of fruit fly captures in each trap.
- Built-in micro camera to photograph trapped insects and send their photos to a central database. Monitored twice a day, while the identification of insects is done by specialized software.
- Quick reaction - Optimization of response time to take decisions. No delay in detecting the occurrence of a pest.
- Allows NPPO to initiate fast eradication or containment activities.
- Potential to increase the number of traps deployed for surveillance.
- Remote monitoring and identification of harmful insects more easily.
- More efficient as larger areas can be monitored.
- Remote-sensing saves time and money usually spent on manually checking of empty traps.
- Save of resources (working hours for travel). Less labour costs.
- Energy-autonomous.
- Cheaper in long-term.
- Cost-efficient.
- Adapted to epidemio-surveillance, research (population dynamic, dispersal studies), SIT.
- Useful for monitoring and for scientific studies.
- Easy access to data with mobile terminals, rapid and timely, high efficiency.

Potential barriers to adoption

- Further development of material (batteries, energy supply, camera resolution, wi-fi connection in rural areas, etc.) necessary.
- Trap efficacy.
- Accurate identification of species is high but not 100%. More reliable identification of species is needed.
- Correct identification when trap is overloaded with different species including non-pests.
- Reliability of remote connect ability.
- Operators' unfamiliarity with computer tools. Technical requirement.
- Some surveys require high amounts of survey points (traps).
- Costs of traps and deployment. Prices of e-traps are higher than conventional ones.
- High costs for maintenance.
- Protection from tampering with trap contents.
- Protection from theft and vandalism.
- Device cost and accuracy of adult fly classification.

Strategies to facilitate adoption

- Find a sponsor (e.g. IAEA) and send traps (paid for by them) individually, free of charge, to potential users to show them the advantages so that they subsequently want to buy some themselves.
- Contacts with companies providing digital services for agriculture.
- Lower prices improving affordability. (Use the cheapest components to reduce the price of a e-trap, FF use to have good spread average, and usually you need a trap for every 150-200 ha surveyed.)
- Co-financing and included in agriculture subsidies (subsiding costs of trap and trap deployment).

- Mass production.
- Improve protection of trap, trap contents and trap data.
- Adapted training for agricultural advisors.
- More research necessary.
- Communicate broadly.
- Presentation in major stakeholders such as EFSA, EPPO, EU directorates and NPPO. Presentation in scientific meetings and publications in grey literature and mainstream papers.
- It is worth of promoting and extension on orchard and port etc.

Identification tool: Electronic muti-entry identification keys for adults & larvae ID

Description

The multi-entry keys are free IOS and android apps to identify adults and 3rd instar larvae of a list of invasive FF of relevance to Europe[13] (D3.3).

Benefits and strengths

- Improved ID tool with easy access via mobile app.
- Easily accessible to all - Easy use by non-specialist, and links to factsheets facilitate access to further information.
- Multi-entry possibility; figures, graphs, explanations.
- Free available apps.
- Fast and easy way to identify relevant species.
- High accuracy of identification of selected species.
- Could allow for an early and quick identification of infested fruits when carrying out spot-checks on large batches.
- Good and easy to manage information for correct identification of pest, especially quarantine pests. Knowing the potential origin of a quarantine pest outbreak is very useful to adopt prevention measures and reinforce phytosanitary measures (border or intra EU movement), avoid the spread to new territories.
- Easy operation with mobile terminals

Potential barriers to adoption

- Limited number of species - The range of covered species is appropriate but not exhaustive.
- Language barrier, coverage.
- From technique, there is less potential obstacles to its adoption except for larva.

Strategies to facilitate adoption.

- Translation, review after time and inclusion/exclusion of other taxa.
- Integrate as appendix in ISPM.
- Promotion of app at target groups (staff an entry points of import).
- Promote the use - e.g. at universities as teaching material in courses such as applied entomology and IPM.

[13].

- Presentation in major stakeholders such as EFSA, EPPO, EU directorates and NPPO, and phytosanitary authorities. Presentation in scientific meetings and publications in grey literature and mainstream papers.

Identification tool: Molecular ID LAMP

Description

Rapid-Molecular-Pest-ID tools and protocols for intercepted FF (D3.4, 3.5)

Benefits and strengths

- Laboratory technique quite current for correct pest identification.
- Facilitation of on-site identification by non-specialist.
- Ease of use.
- Fast ID, in-situ ID.
- Potential for an unambiguous species determination.
- Free development that can be easily adopted at minimal cost.
- May only for larva identification.

Potential barriers to adoption

- Familiarity with technique.
- The methodology must be sufficiently robust to produce unambiguous results under suboptimal conditions (e.g. at border control posts).
- Without any major obstacle for adoption.

Strategies to facilitate adoption

- Compulsory diagnostic protocol for interceptions or new outbreak confirmation.
- Training sessions to potential end-users.
- Presentation in major stakeholders such as EFSA, EPPO, EU directorates and NPPO, phytosanitary inspectors. Presentation in scientific meetings and publications in grey literature and mainstream papers.
- If the tool is sufficiently robust and cost is acceptable, no specific strategy will be needed.

Automated pan European alert systems

Description

A comprehensive computer assisted system that provide real time detection alerts for invasive FF (D5.4).

Benefits and strengths

- Real time information.
- Quick detection to enable a quick response to eradicate any potential FF invaders at large scale and react fast in implementing eradication or containment actions.
- Homogeneous surveillance for pests across Europe.
- Comparability of data between locations and seasons.

- Automatization will allow to increase the density and overall number of traps deployed for surveillance.

Potential barriers to adoption

- An automated alert of registered stakeholders is problematic, as, in the absence of an official confirmation, it will create legal uncertainty.
- The cost/price of e-traps and modeling services.
- Need a broad adoption at the country level.
- Need may be specific founding by each country/ government.
- It is the same as the DSS-Alert system.

Strategies to facilitate adoption

- Lobbying policy makers and EPPOs.
- EU commission and EFSA could make compulsory homogeneous survey methods for pests by e-traps. Real time detection and alert launching to EU commission and other member states (transparency).
- An alert system must not interfere with procedures laid down in harmonised EU legislation: an alert of stakeholders always requires a confirmation by the competent authorities.
- Presentation in major stakeholders such as EFSA, EPPO, EU directorates and NPPO. Presentation in scientific meetings and publications in grey literature and mainstream papers.

DSS-Alert: Dynamic (real-time) pan-European forecast toolbox

Description

A computer operating toolbox that provides estimates regarding risk of arrival, and population growth of target invasive FF at various levels (D5.3, D5.4, D5.5).

Benefits and strengths

- In-silico toolbox for alerting decision makers about introduction and establishment risks of *Bactrocera dorsalis* and *Bactrocera zonata*.
- The dynamism and ability to harness weather forecasts to see the emerging risks, rather than just the historical patterns of fly populations.
- May provide updated information, risk assessment maps at weekly intervals that can be considered at EU and national level for improving detection and perhaps interception fast decisions that may mitigate risks.

Potential barriers to adoption

- Associated cost of using the tool.
- There are potentially different obstacles for the three sets of stakeholders for this toolbox. At the broadest level, there is EFSA/EPPO/DG SANTE. There are likely few obstacles to their adoption of the CLIMEX niche models. In the middle scale, we have the inspection agencies. The biggest obstacle to adoption will be knowledge of the system, and perhaps a little training. At the finest level, we have the pest managers. The obstacles here are numerous: knowledge of the system, an expectation that the services will be provided for free, etc. In the middle and finest scale, there may also be a problem in terms of how the stakeholders need/want the information packaged.

- At this stage, it is probably only useful for regulatory authorities.
- Regulatory aspects that need to be overcome.

Strategies to facilitate adoption

- Tailor tool for other users, such as grower's organizations (e.g., fruit fly free areas and low-prevalence).
- An outreach to each of these sectors of stakeholders will be required. The upper and middle scales are relatively easy to address, through targeted meetings. Accessing farmers and agronomists will be more difficult, requiring us to access a diverse range of communications channels in various languages. This will include webinars and social media and industry magazine pieces.
- Presentation of the tool at major stakeholders such as EFSA, EPPO and EU directorates. Presentation in scientific meetings and publication in mainstream journals and grey literature. Aggressive dissemination campaign in social media.

4.3.2 Strategies and tools for improved fruit fly management

In-Silico boosted Off season IPM paradigm

Description

The innovative strategic approach "OFF-Season focused IPM" is applied where and when the pest is "most vulnerable" (localized low population densities)(D6.3, D6.4).

Benefits and strengths

- Establishment of a trapping network early in season for early detection of FF.
- Reduce pesticide application during on season.
- Reduce the spread of the pest fruit fly into other areas.
- Finding and destroying overwintering pest fruit fly populations will reduce the effort required to manage them during fruit set and maturation.
- Comprehensive management of the fruit fly population. Holistic and sustainable approach that considers the whole seasonal biology.
- Integration of several ecological sound tools.
- Reduce monitoring costs.

Delving deeper into the feedback from farmers in the field plots regarding the FF-IPM approach and control strategies. The following benefits were identified:

- Conventional farmers are concerned about the future of conventional farming, especially about the limited active ingredients of pesticides currently in use and the absence of other well-known and well-established strategies or methods that can provide similar effectiveness in crop protection. Therefore, they are extremely interested in alternatives for fruit fly control.
- Farmers in the field plots were extremely interested in the methodology developed by FF-IPM to develop specifically adapted strategies. The detailed collection of data regarding host phenology, medfly population dynamics and inputs- outputs efforts, provide them with a powerful tool which can prove and guarantee the product quality. Furthermore, they can use the data and the models to be more targeted and specific in their applications and staff effort.

- Overall, the farmers show interest in adopting other systems and are willing to understand more regarding the ecological dynamics of their farms which reinforces the potential for the FF-IPM strategies.
- The farmers are extremely positive about the PESTonFARM model and the mass trapping method. They are pleased about the technical consulting that FF-IPM experts provided in the last years and propose that a series of technical workshops could be organized to disseminate the information among all the stakeholders so these new strategies can be applied in an area-wide scale.
- The owners of the organic farms expressed their interest regarding new strategies such as mass trapping and especially the targeted mass trapping method. They are also interested in predator-based control based on enhancement strategies. They recognize the need of collecting more data about medfly soil predators by screening variable landscapes.
- According to farmers a series of technical workshops could be organized to disseminate information among all the stakeholders so these new strategies can be applied on an area-wide scale.
- With mobile terminal joint in network.

Potential barriers to adoption

- Pest FF may migrate from urban, through peri-urban and into rural commercial horticulture - meaning that Off Season work would need to be done in urban locations.
- Finding overwintering sites is difficult.
- Lower performance under high population densities, the cost in such cases might be high as well.
- The cost of alternative methods and strategies needs to be lower than pesticides, as farmers' profit margins are already very low and therefore farmers cannot use more expensive tools than pesticides. Farmers will adopt alternative methods if they mean greater profits and economic benefits.
- Farmers must be convinced to make applications when the fly seems to be absent.
- Whole-of-community compliance is also very difficult.
- Lack of extension services. Farmers need more support and wider information.
- Alternative methods must be readily accessible on the market and easy to apply.
- In off season, low population density and climate the potential obstacles to its adoption.

Strategies to facilitate adoption.

- With stakeholders and final users.
- Use heat/thermal imaging to find overwintering sites.
- Create artificial overwintering sites.
- More public education is needed to target urban sites. Sometimes house gardens and sentimental plantings of fruiting trees on commercial orchards are "forgotten about" when IPM is applied to the rest of the orchard. More grower education is required.
- Presentation of the tool in growers' associations, individual growers and plant protection authorities. Consider expanding the pilot testing in different agricultural settings. A LIFE EU or other programs might be interesting to consider.

DSS-Virtual-Farm

Description

The Virtual Farm Decision Support and Service Toolbox is a specialized software for designing locally adapted and optimized IPM strategies and farm specific IPM scenarios. It simulates a local Pest-Terrain-Weather-IPM system and enables the simulation of complex pest management scenarios and adapting them to the local conditions BEFORE empirically testing and implementing them on the farm (D6.2).

Benefits and strengths

- It gives useful scenarios that incorporate the economic component of pest management, including population growth at spatial scale and considers the particularities of European farming, landscape, and social environment.

Potential barriers to adoption

- The need for farm digitalization.
- Possible cost, and laborious requirement for baseline background data collection. However, recent technology may overcome some of these aspects.
- Depend on experts is the potential obstacles to its adoption.

Strategies to facilitate adoption

- Included in a commercial package of digital services that includes all the key pests of a crop.
- Presentation in NPPO, growers and growers organisation. Presentation in scientific meetings and publications in grey literature and mainstream papers. Supported extensive pilot testing through a LIFE project.

Control tool: Nematode biocontrol tool

Description

This novel tool consists in the Off-Season application of commercially available strains of entomopathogenic nematodes (EPN) as a soil drench to control the Mediterranean fruit fly (D4.1).

Benefits and strengths

- Can improve the off-season management.
- Off season performance of EPN very high against the first of the overwintering generation.
- The ability of nematodes to penetrate fruits hunting larvae is remarkable and can contribute to reducing the overwintering stages of some species.
- Targeted treatment of overwintering populations.
- Potentially quite effective-environmentally friendly.
- Ease of application.
- Safe for the user.
- No pesticide residues on fruits, IPM tool.
- To kill larva in soil may a good tool.

Potential barriers to adoption

- Extra effort for monitoring FF off-season and grower's reluctance to treat off-season.
- Local strains are more effective but not commercially available.

- Time of application - Soil drench applications are very labour consuming tasks.
- High cost might be the only obstacle since EPN are already in market.
- Prices of nematodes use to be high, and their handling and storage is sometimes difficult (living organisms).
- Risk about specificity and weather constraints for efficacy.
- Control effect is the potential obstacles to its adoption

Strategies to facilitate adoption and policy recommendations.

- Education of growers. Work through co-operatives. Area wide monitoring of overwintering sites of fruit-flies.
- Extend field trials with stakeholder involvement, lower costs (if market is wider).
- Include in a complete IPM package.
- Presentation in NPPO, growers and growers' associations.
- Presentation in scientific meetings and publications in grey literature and mainstream papers.
- Develop more automatised application techniques.
- To be propose as a curative method.

Control tool: Ground-dwelling-predator-based biocontrol tool

Description

Enhancement of populations of soil-dwelling predators for the control of soil-inhabiting developmental stages of the Mediterranean fruit fly (mature larvae, pupae and emerging adults) through the establishment of a ground cover, either as sown green cover of the grass *Festuca arundinacea* (Poaceae) or as a mulch of straw (D4.2).

Benefits and strengths

- Biocontrol tool that will decrease/ limit the use of chemical insecticide.
- Sustainable reduction of overwintering fruit-fly populations.
- A sown cover of Festuca is cheaper to maintain that either BS or a mulch of straw. It dramatically enhances the density of the most active potential soil predators of C. capitata.
- The establishment of a ground cover of grass, or a mulch of straw may promote populations of soil-dwelling predators of FF.
- It also may better hold rainwater, increasing seepage and delay water runoff.
- Use of native fauna for fruit fly management, targeting low populations early in season. Sustainable interventions to modify habitat. Integration with other control strategies, since the ground found is considered.
- Such biological control is always superior to the use of chemical insecticides.
- Ecofriendly control tool.
- Growers already know the beneficial effects of FA covers to improve biological control for other pests (aphids...).

Potential barriers to adoption

- Grower's reluctance to change practices for mulching or grass coverage.
- Many farmers like bare soil (BS); they may reject a cover based on a false myth that it may be more expensive to implement and maintain than BS.
- Farmers may also be afraid of fire affecting the cover during the hot-dry summer period.
- The farmer must be willing to invest in implementing the proposed soil management.

- It might affect the irrigation and water supply to the trees and may enhance major plant pathogens such as Alternaria fungi. It also might interrupt harvesting.
- Water shortage.
- Water competition of the cover vs the crop.
- Labour in modifying the orchard environment and meticulous use of other products.
- Cost and working time.

Strategies to facilitate adoption.

- Work through co-operatives.
- Same as with other control options, the establishment of a ground cover could be subsidized.
- Apply and improve it.
- Using European funds to encourage grassing of orchards.
- Presentation in NPPO, growers and growers associations. Presentation in scientific meetings and publications in grey literature and mainstream papers.
- List the other advantages of this measure such as the reduction in N leaching.

Control tool: Entomopathogenic fungi-based biocontrol tool

Description

Soil applications of the commercially available mycoinsecticide Botanigard® WP22, based on a strain of the entomopathogenic fungus *Beauveria bassiana,* to control soil-dwelling life stages of the Mediterranean fruit fly (mature larvae, pupae and emerging adults.) (D4.3).

Benefits and strengths

- Biocontrol tool that will decrease/ limit the use of chemical insecticide
- Ecofriendly control tool.
- Reduction of overwintering populations. Persistence of fungi in the soil
- Preventive treatments efficient on and off season, potentially remanent (less treatment needed), contact insecticides.
- Easy application, no pesticide residues, IPM tool.
- A biological control agent, which has not shown very high efficacy in the FF-IPM trials. There is potential but additional work is required and further testing.

Potential barriers to adoption

- Water shortage and limited humidity – Fungi usually works in humid environments, which are not easily found in Mediterranean conditions apart from winter and spring.
- The main critical periods for *C. capitata* damages are late spring, summer and early fall, the most unfavorable weather conditions for EF.
- Mass production for soil treatment.
- High cost and moderate efficacy.
- Screening high efficiency isolates is the potential obstacles to its adoption.

Strategies to facilitate adoption

- Combination with mulching increases moisture.

- Lower prices, performing more efficiency tests in different environments and broadly communicate on them.
- Test other strains with higher efficacy.
- Presentation to NPPO highlighting pros and cons. Presentation in scientific meetings and publications in grey literature and mainstream papers.

Control: Lure and Kill

Description

A protocol for deploying lure and kill systems to manage the populations of the Mediterranean fruit fly Off Season (D4.4).

Benefits and strengths

- Classical method with record of efficacy; exposure of environment, humans or animals to the active substance can easily be minimized.
- Ecofriendly control method.
- Growers are used to mass trapping devices, without pesticide residues on the fruit.
- Relative cheapness allows large numbers of devices per hectare, high target specificity protects beneficials, can be used in organic situations, can be highly attractive (depending on fruit fly species and attractant).
- Already existing technology that can be strategically used to control low population off-season. FF-IPM is unique in shifting the scope of IPM and the use of respective already developed tools.

Potential barriers to adoption

- No attractants available for some pest species, female FF are less targeted, pesticides not secure in device (exposed to rain or irrigation), need to be a component of fruit fly management not just "set-and-forget" stand-alone strategy. May not work well under very high fruit fly populations especially where there are non-compliant neighboring orchards, abandoned orchards, untended urban gardens and community/State/Crown-owned feral fruiting plants.
- Sufficient efficacy only in combination with other measures.
- High volume of waste generated in the field (100 plastic devices every year per ha), liquid devices are not practical (labour requirements to install and to re-fill the device during the season).
- Cost of the tools. High prices of mass trapping in the market.
- More data about medfly soil predators by screening variable landscapes is needed.
- High effective Lure and Kill products both for male and female.

Strategies to facilitate adoption

- Demonstrate to the final users the efficacy and the beneficial to the environment.
- Create a system of strategies incorporating lure-and-kill devices with other components (orchard hygiene, monitoring traps, manual fruit inspection, etc) that should be used in all orchards. Increase whole-of-community compliance/ownership.
- Presentation in NPPO, growers and growers associations, highlighting the benefits of early use of Lure and Kill. Presentation in scientific meetings and publications in grey literature and mainstream papers.
- Some less waste producing alternatives could be tested (long life attract and kill paints...). Recommendation to facilitate the register of Lure and kill devices/techniques in the EU.

- The need to approve the attractant as well as the killing agent as plant protection products is a common obstacle for mass trapping; data waivers need to be developed which convince risk assessors and risk managers.

The findings regarding stakeholders' perspectives regarding the FF-IPM strategies and tools was taken into account for the formulation of recommendations to policymakers regarding the adoption of novel FF management tools and strategies.

5 Communication with high level policy and decision makers at EU and international level

One of the strategic priorities of FF-IPM has been to engage with high level policy and decision makers at the regional and EU levels. This was important firstly to ensure that the tools and strategies developed aligned with the needs of these organisations. This engagement was also critical to advocate for the integration of the FF-IPM solutions into existing workstreams, standards legislation and regulations and to examine how this could be done.

The project interaction with organizations such as EPPO, DG SANTE, EFSA and the Joint division FAO/IAEA aimed at sharing project findings, gauge the perspectives of these organizations regarding the FF-IPM solutions and also advocate for the adoption of FF-IPM strategies.

This section presents some of the communication efforts and highlights the points of view of representatives of some of these organizations regarding FF-IPM.

The European Plant Protection Organization (EPPO) acknowledged the importance of novel or improved trapping tools and approaches for surveillance activities, as well as novel or improved diagnostics methods. The latter ones could be implemented into EPPO diagnostic protocols and EPPO standards or provide sequence data for the EPPO Q-Bank database. Additionally, the new forecasting tools and the novel IPM approach were expected to improve the regulation of quarantine pests. The need for early alerts and detailed operational contingency planning were equally considered important[14].

The EC DG SANTE views the new approaches and developments of tools for trapping, e-trapping and detection and e-detection of quarantine fruit fly species as highly effective, and if applied as automated and independent trapping methods as most important to improve early detection at import border control. Furthermore, the new forecasting tools and the virtual farm toolbox were considered valuable improvements. However, in this context, both the importance and the difficulties related to the involvement of local communities and different stakeholder groups to implement novel IPM tools into practice were emphasized[15].

The Joint FAO/IAEA division[16] advocates for the integration and combination of different methods with SIT, which has a proven track record, but works only under certain conditions and is not adequate for all

[14] Cf: Interview with Françoise Petter, EPPO, Fruit Flyer FFIPM Bulletin • ISSUE 01 • September 2020 https://mcusercontent.com/d9f0685739e7f506708d40719/files/6079607d-cabf-4c29-8b9d-ac08c685f632/FFIPM_newsletter_01_spreads.pdf

[15] Cf. Interview with Wolfgang Reinert, DG SANTE, FFIPM Bulletin • ISSUE 03 • October 2021, FFIPM Bulletin • ISSUE 04 • March 2022 https://fruitflies-ipm.eu/wp-content/uploads/2021/06/FFIPM_newsletter_03.pdf ; https://fruitflies-ipm.eu/wp-content/uploads/2021/07/FFIPM_newsletter_04.pdf

[16] Cf. Interview with Rui Cardoso Pereira, FAO/IAEA FFIPM Bulletin • ISSUE 02 • March 2021 https://fruitflies-ipm.eu/wp-content/uploads/2021/03/FFIPM_newsletter_02_spreads.pdf

situations nor for all pests. The most important imminent threats for European fruticulture are posed by the expansion of the medfly due to changing climate conditions and the invasion *B. dorsalis* and *B. zonata* which are already established in Africa, and which have already been detected in Europe. The melon fly (*Zeugodacus cucurbitae*) is already invading Africa. Another threat is the possible invasion by mosquitoes which are vectors for human diseases.

EFSA stakeholder engagement. A landmark event was hosted by the European Food Safety Authority (EFSA) in Parma, Italy, in 2024 showcasing the achievements of FF- IPM Project. This workshop was a unique opportunity to focus into the latest advancements in Fruit Fly Management, bringing together experts and stakeholders from various fields. It was an important opportunity to engage in insightful conversations on the challenges and opportunities in Fruit Fly Management and reflect on the progress made and discuss the future of FF-IPM tools.

A stakeholders Consultation Workshop in Athens, Greece[17]

Organised by the Benaki Phytopathological Institute and University of Thessaly, in 2022, presented the FF-IPM's products and discussion on stakeholder needs and how the FF-IPM products can cover them. Following a fruitful discussion, actions and recommendations for improvement of products were noted to be implemented. Stakeholder participants.

6 Tailored briefing materials to communicate with top target groups

A web platform was developed to communicate project results about the various strategies and approaches with various target groups. The FF-IPM Platform is a dynamic web-based foundation for dissemination of technologies, know-how, innovative tools, and expert services, to empower stakeholders across all sectors along the fruit production and processing chain (platform.fruitflies-ipm.eu).

The purpose of this platform is to link services and products developed either by FF-IPM, or other researchers and innovators across the EU and beyond, thus providing technical support to the end-users. It acts as an easy-to-use, intuitive showcase of the expert services and tools available, allowing visitors to quickly find a tool or service that suits their needs.

The FF-IPM platform gathers information on all the tools developed (https://platform.fruitflies-ipm.eu/product-category/tools/).

The Platform archives project accomplishments to ensure open access and public availability without requiring user login and provides visitors with a powerful search bar that enables querying based on keywords, which can represent either general information (Company, Author, Title etc.) or more specific parameters like Geographical Area.

Results are listed in either alphabetical or publication date order and can further be filtered by the user. Each entry contains a summary, a few basic keywords related to the results, a related picture, and a downloadable link. Users can also leave comments/reviews under the different publications.

Storage information and documents generated during the project and stored on the Intranet of the Management Platform will be protected for at least a year after the project completion, and longer according to subsequent decisions taken by the Executive Board.

7 Policy recommendations

This chapter provides recommendations directed at policymakers aimed at facilitating the adoption of FF-IPM strategies and tools. The recommendations encompass a broad spectrum of measures to support the

[17] 21 participants from regional plant protection services, local industry and visiting researchers from CERVANTES (Australia), CORVUS (Poland), ARO (Israel) and CIRAD (France) participated 4 sessions based on their interest and field of concentration.

adoption of the FF-IPM prevention & early detection and identification tools as well as the strategies and tools for improved fruit fly management in the field.

The wide range of strategies and tools developed by the project have the potential to influence fruit fly management at several scales including international, the national, the regional and the farm levels. Accordingly, the policy recommendations offer recommendations that have an influence on adoptability at these four levels.

7.1 Strategies and tools for early detection of invasive FF

Facilitate the implementation of the surveillance, forecasting, early detection and identification methods developed in the project by NPPOs. For trade moved pests this applies equally to detection and identification at points of entry and points of exit where existing protocols should be adapted accordingly.

Incorporate DS-Alert system for fruit fly real-time surveillance and forecasting in Europe

Encourage the adoption of the Decision Support-Alert system, a dynamic early warning toolbox, which provides weekly European climate-related fruit fly risk maps and alerts (see e-traps) at pre-border, border and post-border level to improve surveillance by border biosecurity operators for appropriate timing and location of plant health threats. Policymakers should facilitate access to this system for all key plant health and plant protection stakeholders.

Incorporate ID tools into diagnostic protocols and standards on phytosanitary measures

The novel electronic multi-entry keys for the identification of adult FF and 3rd instar larvae based on morphological characters for improved prevention of trade related pest introduction and early detection should be validated by plant health reference laboratories on European and National level to be included into or as approved diagnostic protocols in Europe.

Additionally, these diagnostic protocols for fruit fly identification should be adapted by a potential inclusion of the developed LAMP (Loop-mediated Isothermal Amplification) technologies, DNA-barcodes and diagnostic Single Nucleotide Polymorphisms (SNPs) to enhance the capacity for rapid, unambiguous early detection and identification of invasive species.

Integrate FF-IPM early detection tools into pertinent European regional standards for the improvement, and/or adaptation of current inspection measures.

The novel species-specific automated e-Trap system for early detection should be implemented as monitoring and real-time alerting tool (see DS-Alert) of each fruit fly trapping event on national or regional (pan European) level to improve current inspection measures both at border entries or exits and in the field.

7.2 Strategies for improved fruit fly management

Provide incentives to the adoption of alternative environmentally friendly methods.

For FF-IPM strategies to be fully adopted by farmers they must be economically viable. Develop policies that promote the adoption of ecofriendly methods such as the ones developed by FF-IPM. Consider policies to support farmers transitioning to these methods and that can help deal with the risk. This can be through financial incentives, and/or grants or subsidies to reduce costs of alternative control methods to ensure they are competitive with pesticides. With the massive adaptation of these new methods production prices are expected to fall, so that initial subsidies can be phased out eventually.

"Farmers are unlikely to adopt IPM broadly unless their risks are covered, and multiple vectors of support are offered. This is a huge commitment for many farmers with a lot of uncertainty involved".

Support the dissemination of the Pest-on-Farm model:

Facilitate access to the PEST-on-farm model, or a user friendly platform, among National Plant Protection organizations, extensions services and IPM advisors and farmers. The model enables the development of strategies tailored to farm level to deal with FF. It allows for the in-silico simulation of different strategies on this level, including costs and benefits for each strategy. The introduction of bio-diversity friendly combinations of methods for protection that rely less on the pesticides may at the first look be more expensive for the individual farmer/producer than the use of pesticides, but this excludes the overall costs incurred and currently born by the society as a whole, such as health costs and environmental costs. The novel approaches should be combined with climate resilient strategies so that farmers/producers will have more incentives to adopt them.

Policies should also provide incentives to the integration of this model into individual farmer strategies, emphasizing the reduction of pesticide use and the incorporation of biodiversity-friendly methods.

Support the production of information and platforms for dissemination of information:

Support the development of briefing materials, building on the materials developed by FF-IPM adapted to the context of specific fruit production areas and translated in national languages.

Produce training materials directed the very diverse communities of farmers/producers and extension services.

Develop packages specifically directed at organic farming.

Support the development of accessible internet platforms to provide on time information about new and existing fruit fly threats to all actors. Include automatic translation in all platforms.

Use multi-channel approaches including established, new and upcoming technologies to reach decision-makers on all levels.

Enhance training about IPM strategies for fruit fly including FF-IPM project

Information/training of national plant protection authorities and staff: Support training of national plant protection authorities and their staff on the new approaches for integrated control of FF including the off/on season paradigm.

Strengthen, training and extension services to farmers: Support the training of farmers/producers in the new approaches for fruit fly control including the off/on season paradigm.

Training of other stakeholders. Support specific training for trainers and other multiplicators. Include modules about Fruit Fly IPM off/on season approach into academic and professional courses. Also include risks and threats that are not directly fruit fly related, but which have the potential to impact on FF and fruit production (e.g. climate change, international trade dynamics, disruption of supply chains, market volatility, political upheavals, epidemics, etc.). A list of 25 training modules have been developed by the FF-IPM project to support training of stakeholders to developed tools and to the management of invasive FF in general (D8.6).

These strategies should be expanded beyond Europe to areas from which Europe imports.

Strengthen and support research and innovation.

Support more research and adaptation of the FF-IPM that address the specific needs and contexts of farmers and specific agroecosystem and that address the specific needs and requirements of farmers/producers, traders, (post-harvest treatment, detection, etc.), and agroecosystems as well as changing consumer preferences. Include food waste which is at alarmingly high levels and reduces strongly the overall efficacity of increased fruit production through improved plant protection.

Take into specific consideration the perceptions, decision-making and behaviour of farmers/producers facing threats, risks, and innovations.

Consider the environmental and health costs of pesticides in decision making.

To facilitate the adoptions of Fruit fly IPM strategies it is crucial to go beyond the immediate economic considerations for farmers and include broader societal considerations into decision making processes at all levels. Policymakers should promote the use of cost benefit analysis models that extend beyond direct costs considerations but also take into account broader societal costs and benefits including human health and to the environment. By doing so, the true societal value of the IPM alternatives can be integrated in decision making processes.

Developing National fruit fly action plans that integrate FF-IPM strategies: Facilitate the development of national fruit fly action plans and consider incorporating the FF-IPM strategies and tools for early detection and identification in them.

8 Conclusions

The FF-IPM project has developed novel, applicable knowledge-based approaches and innovative tools for prevention, early detection, forecasting and management (Off-Season paradigm, IPM, biocontrol) to cope with the risks posed by invasive/emerging FF to European horticultural farmers, fruit production industry and trade. Nearly all of the mentioned tools were developed to a ready of use level or are in use already.

The specific project objectives to create a fundamental paradigm shift in FF IPM towards "OFF-Season" management of emerging pests, to enhance the capacity for "ON-Season" FF management through innovative in-silico boosting the existing IPM toolbox, and the development of novel tools and services, to enhance the capacity to manage the phytosanitary risks of FF invasions and range expansions propelled by the climate change, human traffic and fruit trade, through development of innovative prevention, detection and diagnostic tools and services, to enhance implementation of EU plant health policy and provide knowledge-based support to relevant local, regional and EU-wide plant health planning and policies were all met.