Conference Programme

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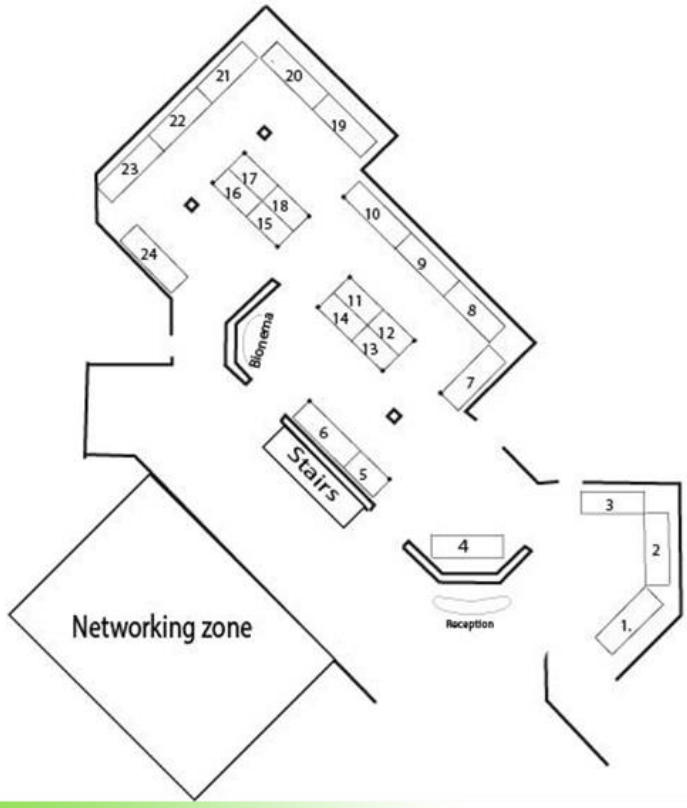
Exhibitor Layout – Taliesin Arts Centre



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20. Agor IP
23.IPC
24.Burleigh Dodds

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Conference Session Topics

	Session Title	Chair
1	**IPM - Challenges and Solutions**	**Dr Ian Baxter** (IBMA UK & Syngenta)
2	**Multifunctional Microbes - Multitrophic Interactions – PART 1**	**Dr Farooq Shah** (Swansea University, RAZBIO)
3	**Remote sensing & UAVs**	**Professor Peter North** (Swansea University)
4	**Multifunctional Microbes -Multitrophic Interactions – PART 2**	**Professor Frédéric Francis** (University of Liege)
5	**IPM and Sustainability**	**Dr Arben Myrta** (Certis Belchim)
6	**Volatile Organic Compounds and Semiochemicals - uses in IPM**	**Dr Owen Jones** (Lisk & Jones Consultants Ltd)
7	**Computational Science & Sensor Applications to Pest Management**	**Dr Will Allen** (Swansea University)
8	**Funding Opportunities**	**Dr Farooq Shah** (Swansea University, RAZBIO)
9	**POSTERS & STAND**	
10	**Nuisance Pest & Disease Vector Control Part 1**	**Dr Peter McEwen** (PKMC Consultants)
11	**Microbial & Macrobial BCA: Production and Use**	**Professor Dan Eastwood** (Swansea University)
13	**Nuisance Pest and Disease Vector Control Part 2**	**Dr Kanagasooriyam Kanagachandran** (Rentokil Initial Ltd)
14	**New IPM: Development, Regulatory and Training**	**Jennifer Lewis** (IBMA)

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Tuesday 5th September

		Welcome and housekeeping – Taliesin Arts Centre (Lecture Theatre)	
9.00		**Session 1: "IPM Challenges and Solutions"** **Chair: Dr Ian Baxter** *IPM fits well in the One Health framework but faces many challenges. This session looks at some of the approaches used in different sectors by colleagues from around the world.*	
9.00	**9.10**	**Ian Baxter** (Syngenta) Welcome and housekeeping	
9.10	**9.40**	**Todd Kabaluk** (Agriculture and Agri-Food Canada, Canada) **Protecting potatoes from pestilent elaterids: using biocontrol and new technologies to reframe traditional approaches.**	
9.40	**10.10**	**Sean Moore** (Citrus Research International, South Africa) **IPM implementation: all the tools but too many rules**	
10.10	**10.30**	**Aoife Dillon (**FERA, UK**)** **IPM of Emerald Ash Borer**	
10.30		**Refreshments and Networking Break**	
11.00	**11.20**	**Shafqat Saeed**, Naeem Iqbal, Muhammad Nadir Naqqash, Muhammad Asif Farooq, Farrukh Baig (MN Univ of Agriculture Multan, Pakistan) **IPM of Cotton: A ray of hope in Pakistan**	
11.20	**11.50**	**Chengshu Wang** (Shanghai Institute of Plant Physiology and Ecology, PRC) **Biocontrol application and monitoring of *Beauveria bassiana* in China**	
11.50	**12.10**	**Norman Carreck** (Carreck Consultancy Ltd., UK) **Current and future pests of honeybees and their control, and honeybees as biomonitors.**	
12.10	**12.30**	**Jozsef Vuts** (Rothamsted Research, UK) **Lure development for the stored legume pest, *Acanthoscelides obtectus***	
12.30		**Lunch and Networking Break – Taliesin Arts Centre**	
14.00		**Session 2:** Lecture Theatre **"Multifunctional Microbes - Multitrophic Interactions – PART 1"** **Chair: Dr Farooq Shah** (Swansea University, RAZBIO) *Many microbial agents developed for plant protection have been shown to possess many other useful attributes such as plant growth stimulation and increasing plant resistance to*	**Session 3:** The Mall **"Remote sensing & UAVs"** **Chair: Professor Peter North** (Swansea University) *Remote sensing and UAVs play an increasing important role in pest monitoring and control. Together with semiochemicals they provide early warning systems that allow growers and public health officials to take informed and timely action.*

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		stress and influencing the behaviour of beneficial arthropod predators and parasitoids.	
14.00	**14.20**	**Frédéric Francis** (University of Liege, Belgium) **Combined strategies to promote multi-trophic interactions in biocontrol**	**Guy Hendricks** (AVIA-GIS, Belgium) **Seeing disease vectors from the sky: How far can we go?**
14.20	**14.40**	**Luis Lopez Llorca** (University of Alicante, Spain) **Endophytic Biocontrol Fungi, Chitosan and VOCs for IPM**	**Jacqueline Rosette** (Swansea University, UK) **The use of remote sensing for the assessment of forest growth**
14.40	**15.00**	**Dana Ment** (The Volcani Centre, Israel) **Microbial pest control is taking new shape by novel tailored formulations and harnessing of more ecological attributes**	**Ant Surrage** (Fargro Ltd) **Seeing the Unseen: Optimising crop protection through hyperspectral imaging**
15.00	**15.20**	**Enrique Quesada Moraga** (University of Cordoba, Spain) **The advent of entomopathogenic ascomycetes as multipurpose microorganism for crop protection and production**	**Peter North** (Swansea University, UK) **Remote Observation In Crop Pest and Disease Monitoring**
15.20	**15.40**	**Ivan Dubovsky** (University of Novosibirsk, Russia) **Multifaceted entomopathogenic fungi: Improving the fungi-based products activity against pests and diseases of crops**	**Jon West** (Rothamsted Research, UK) **Monitoring Airborne Plant Pathogens to improve crop protection**
16.00	**16.20**	**Shumaila Rasool** (Institute of Ecology, Netherlands) **Entomopathogenic fungal-plant interactions: an ecological approach to sustainable pest management**	**John Doonan** (Aberystwyth University, UK) **Evaluation of UAS imagery to monitor crop productivity and effectiveness of bioprotectants**
16.20		**Refreshments (Posters and stands) Taliesin Arts Centre**	

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Wednesday 6th September

Welcome and housekeeping – Taliesin Arts Centre (Lecture Theatre)			
09.00		**Session 4:** Lecture Theatre **"Multifunctional Microbes - Multitrophic Interactions – PART 2"** **Chair:** **Professor Frédéric Francis** (University of Liege) *Many microbial agents developed for plant protection have been shown to possess many other useful attributes such as plant growth stimulation and increasing plant resistance to stress and influencing the behaviour of beneficial arthropod predators and parasitoids.*	**Session 5:** The Mall **"IPM & Sustainability"** **Chair**: **Dr Arben Myrta** (Certis-Belchim) *This session will bring information and evidence on the importance of good metrics to measure and monitor over time the sustainability of Integrated Pest Management (IPM) programmes.*
9.00	**9.20**	**Vassili Kouvelis** (NKUA, Greece) **How the evolution of secondary metabolism affects the lifestyle of endophytic entomopathogenic fungi: the case of *Metarhizium brunneum*.**	**Arben Myrta** (Certis Belchim, Italy) **Integrated Pest Management and sustainability: why developing metrics is important?**
9.20	**9.40**	**Alexandra Kortsinoglou** (NKUA, Greece) **Unveiling Genomic Diversity in Entomopathogenic Fungi: Insights from Comparative Analysis of *Metarhizium brunneum* strains**	**Diana Corredor** (Cornell University, USA) **Environmental Impact Quotient (EIQ), a method to compare the environmental impact of pesticides: history and prospects for improvement.**
9.40	**9.55**	**Ibtissem Ben Fekih** (University of Liège, Belgium) **Assessment of two endemic soil-borne entomopathogenic fungi, *Metarhizium brunneum* and**	**Laurence Antonio Gutiérrez** (Certis Belchim, Spain) **Key Performance Indicators (KPIs) proposed by Certis Belchim, to contribute to the improvement of farm**

NEW IPM 2023

		***Metarhizium majus* in a multitrophic interaction context to control beet mild yellowing virus.**	**sustainability that resulted from new Integrated Pest Management (IPM) programmes.**
9.55	**10.15**	**Surendra Dara** (Oregon State University, USA) **Entomopathogenic fungi contributing to sustainable crop production through non-entomopathogenic roles**	**Gabriele Canali** (University of Piacenza, Italy) **Assessing the sustainability of IPM: towards a new model to face the challenges.**
10.15	**10.30**	**Catalina Posada-Vergara** (University of Goettingen, Germany) **Biocontrol at the Root Level: Unraveling the Mechanisms of *Metarhizium***	**Discussion**
10.30		**Refreshments and networking break**	
11.00		**Session 6:** Lecture Theatre **Volatile Organic Compounds and Semiochemicals - uses in IPM** **Chair: Dr Owen Jones** (Lisk & Jones Consultants Ltd, UK) *This session focuses on use of semiochemicals and volatile organic compounds in pest monitoring and pest control programmes. The VOCs can exhibit both semiochemical and pesticidal properties.*	**Session 7:** The Mall **"Computational Science & Sensor Applications to Pest Management"** **Chair: Dr Will Allen** (Swansea University, UK) *Computer science is playing an increasing role in pest management programmes; trap design, screening of semiochemicals, pest identification etc. It will play an even larger role in the future, especially when managing large areas.*
11.00	**11.20**	**Nayem Hassan** (Russell IPM, UK) **Push-Pull - a novel strategy for pest management in protected crops**	**Meelad Yousef** (University of Cordoba, Spain) **Towards the ecological and digital transition in integrated pest management: remote monitoring of the olive fruit fly and its microbial control.**
11.20	**11.40**	**Islam Shoby (**Cardiff University, UK**).** **Unlocking crop protection: Harnessing plant-insect interactions for sustainable pest management**	**Natalie Roberts** (Swansea University, UK) **Using visual modelling to improve pest management products.**

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11.40	**12.00**	**Pierre-Antoine Bourdon** (Swansea University, UK) **Developing new Integrated Pest Management (IPM) strategies against wireworms using volatiles organic compounds**	**Roger Santer** (Aberystwyth University, UK) **Trap colours can be improved rationally by modelling insect colour vision: improving coloured targets for tsetse fly control**
12.00	**12.20**	**Ugo Picciotti** (University of Alicante, Spain) **IPM and biocontrol by VOCs**	**Sam Cook,** SEIMANDI-CORDA, E. BICK **(**Rothamsted Research, UK) **Optical sensors for automated detection and identification of insect pests and their natural enemies in oilseed rape crops**
12.20	**12.40**	**Ene Leppick** (Agriodor, France) **Control of sugar beet yellows viruses by behavioral manipulation of aphid vectors in the field via volatiles**	**Martin Peacock (**Zimmer & Peacock Ltd, UK**) From Field to Cloud – Quantification of chemicals in the Agro-Industries.**
12.40	**13.00**	**Adriana Escudero-Colomar** (IRTA, Spain) **Improving the forecast of *Grapholita molesta* development in apples**	**Moved to Thursday at 12:40**
13.00		**LUNCH and Networking break**	
14.00		**Session 8:** Lecture Theatre **Funding Opportunities** **Chair**: **Dr Farooq Shah**	
14.10	**14.20**	**Paul Laniran** (Innovate UK) **Funding for Research and Innovation in Agriculture**	
14.20	**14.40**	**Stephen O' Leary** (Innovate Edge) **Innovate UK EDGE: Empowering your business innovation to grow and scale**	
14.40	**15.00**	**Dr. Fawzi Belblidia** (Swansea University, UK) **A4I "Analysis for Industry" Funding opportunity**	
15.00	**15.10**	**Refreshments and networking break**	
15.10	**17.30**	**Session 9 – POSTERS & STAND** Everyone has the opportunity to visit posters and stands to discuss with colleagues the posters/products and network.	

18.15	**23.00**	**Banquet at the Arena, City Centre**
19.00	**23.00**	Conference dinner and speeches (serving at 19.30)

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Thursday 7th September

Welcome and housekeeping – Taliesin Arts Centre (Lecture Theatre)			
9.00		**Session 10:** Lecture Theatre **"Nuisance Pest & Disease Vector Control" Part 1** **Chair: Dr Peter McEwen** *Many of the tools and strategies developed for crop protection have the potential for being adapted for use in the management of nuisance pests and disease vectors.*	
9.00	**9.20**	**Owen Jones** (Lisk & Jones Consultancy Ltd, UK) **Attractive Targeted Sugar Baits (ATSBs) as novel tools in mosquito disease vector management**	
9.20	**9.40**	**Colin Berry** (Cardiff University, UK) ***Bacillus thuringiensis* in the control of pest invertebrates**	
9.40	**10.00**	**Martyn J. Wood[1]** (Swansea University) **Development and laboratory validation of a highly effective plant-derived mosquito contact-repellent blend, with weak spatial-properties, that is effective against members of the genera *Aedes* [Diptera: Culicidae], *Anopheles* [Diptera: Culicidae] and *Culex* [Diptera: Culicidae]**	
10.00	**10.20**	**Imroz Ali** (Russell IPM, UK) **Integrated larvicide strategy for enhanced mosquito-borne disease control: controlled release novaluron tablet and eco-friendly silicon spreader.**	
10.20	**10.40**	**Shams Usmani** (M2i Life Sciences)	
10.30	**11.00**	**Refreshments and networking break**	
11.00		**Session 11:** Lecture Theatre **"Nuisance Pest & Disease Vector Control" Part 2** **Dr Kanagasooriyam Kanagachandran** (Rentokil Initial Ltd, UK)	**Session 12:** The Mall **"Microbial & Macrobial BCA: Production and Use"** **Chair: Professor Dan Eastwood** (Swansea, UK)
11.00	**11.20**	**Charles Phillips** (Barrettine Ltd, UK) **FlyMax ULV - Control of mosquitoes without traditional pesticides.**	**Peter Lueth** (Toothpick Co, Kenya) **Kichawi Kill spore powder, the breakthrough in Striga control**
11.20	**11.40**	**Paul Dyson** (Swansea University, UK) **Symbiont-mediated RNAi: using bacteria to deliver RNAi to their insect hosts**	**Mustafa Kilic** (Black Sea Agricultural Research Institute, Türkiye) **Current status of *Halyomorpha halys* (stål, 1855) (Hemiptera: Pentatomidae) in Türkiye and its associated**

NEW IPM 2023

			biocontrol using *Trissolcus japonicus* (Hymenoptera: Scelionidae)
11.40	**12.00**	**Richard Samuels** (Universidade Estadual do Norte Fluminense, Italy) **The use of *Beauveria bassiana* to improve plant development in tomato, *Solanum lycopercicum***	**Ekaterina Grizanova** (University of Novosibirsk, Russia) **How pest resistance to Bacillus thuringiensis helps to improve bioinsecticide.**
12.00	**12.20**	**Chedly Tizaoui** (Swansea University, UK) **Extraction of Essential Oils for Pest Control**	**Yuxian Xia** (Chongqing University, PRC) **Development and mass production of broad-spectrum fungal pesticides against insect pest and plant pathogen**
12.20	**12.40**	**Goria Resquin-Romero** (National University of Asunción, Paraguay) **Entomopathogenic fungi for ant and termite control**	**Robin Dietsch** (Belafeld University, Germany) **Single-cell polymer coating improves desiccation tolerance of *Metarhizium brunneum* blastospores**
12.40	**13.00**	**Deb Roy** (Swansea University, UK) **Hyperspectral analysis of produce**	**Wanissa Mellikeche** (Università degli studi di Foggia, Italy) **Eco-friendly strategy to control toxigenic *Aspergillus* spp. on nuts based on early detection by Loop-mediated isothermal amplification (LAMP) and alternative pre- and post-harvest treatments.**
13.00	**14.00**	**LUNCH and Networking break**	
14.00		**Session 13:** Lecture Theatre **New IPM: Development, Regulatory and Training** **Chair**: **Jennifer Lewis** IBMA *For IPM to be implemented and successful, it takes a multidisciplinary effort from many different quarters. Here, we consider regulation, and training aspects for IPM development*	
14.10	**14.30**	**Holly Alpren** (Defra, UK) **Overview of DEFRA's IPM R&D**	
14.30	**14.50**	**Steve Arthurs** (BioBee Ltd, USA) **Drone delivery of beneficial insects and mites for pest control in open field crops: Grower Training & Experiences from the USA**	

NEW IPM 2023

14.50	**15.10**	**Aoife Dillon** (FERA, UK) **IPM: addressing the challenge in the UK context**
15.10	**15.30**	**Djami Djeddour** (CABI, UK) **Navigating Regulatory Procedures for weed biological control using non-native agents in the UK**
15.35	**15.55**	**Jack Farmer** (LettUs Grow, UK) **Innovation and regulatory challenges in controlled environment agriculture**
15.55	**16.00**	**Jennifer Lewis** (IBMA), **Session closing remarks**
16.00	**16.10**	**New-IPM: Closing Remarks. Professor Tariq Butt** (Swansea University) and **Dr Ian Baxter** (IBMA UK)

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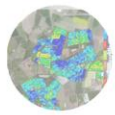


Protecting potatoes from pestilent elaterids: using biocontrol and new technologies to reframe traditional approaches.

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Todd Kabaluk

Agriculture and Agri-Food Canada, Agassiz, British Columbia, Canada (Todd.Kabaluk@agr.gc.ca)

Agroecological habitats are often diverse, with resident elaterids (wireworm larvae and click beetle adults) having multiple venues for sustenance and reproduction. In potato production alone, there are typically multi-year rotations with other plant families, field margins or hedge rows, and a variety of natural refugia, in addition to the crop of tubers – the food source conferring the insect as a pest. Considered in this way, wireworm control using a conventional pesticide application is narrow in scope. By understanding the chemotactic responses of wireworms and click beetles, we can exploit compounds that heighten their exposure to pathogens applied as a biological control. With novel application technology e.g. a drone and novel pest control product formulations, we can target the pest in otherwise inaccessible habitats or during non-cropping periods. Such a comprehensive approach could finally lead to the maintenance of below-threshold wireworm levels and provide crop protection for the long-term.

IPM implementation: all the tools but too many rules

Sean Moore
Citrus Research International, Gqeberha, South Africa; Centre for Biological Control, Rhodes University, South Africa

There are several research projects in southern Africa, dedicated to developing and improving biopesticides for use in Integrated Pest Management (IPM). Some of the recent highlights are the discovery of a Cydia pomonella granulovirus (CpGV) that can overcome codling moth resistance to CpGV, the discovery of the first NPV in the Grapholitini tribe of tortricids, with a host range including several globally important lepidopteran pests, and a novel formulation found to significantly improve baculovirus efficacy. Unfortunately, this is in an environment of seriously eroded IPM implementation. Using citrus production in southern Africa as an example, never before has such extensive use of biocontrol agents and biopesticides been made, but ironically, IPM has never before been so undermined. Mass reared parasitoids and predators are augmented extensively. Biopesticides in the form of baculoviruses, entomopathogenic fungi and nematodes are applied to thousands of hectares annually. The Sterile Insect Technique, mating disruption, attract and kill and mass trapping are also used on an area-wide basis over thousands of hectares. However, the mere use of biological and biorational modes of pest management does not constitute an IPM approach. IPM is undermined by a number of factors that are difficult to manage. Most of these factors emanate from the European Union (EU). Ironically, despite the EU driving several initiatives that appear to favour IPM, most recently the European Green Deal, a number of European initiatives have the opposite effect. These include the ongoing attrition of available chemistries for pesticidal use, a reduction in residue tolerance by both regulators and retailers, and scientifically unjustified phytosanitary regulations. All of these serve to dictate pest management programmes, rather than allowing monitoring-based decision making, as is central to a true IPM programme. Despite these challenges, we continue to strive for the successful implementation of true IPM.

IPM: Addressing the challenges in the UK context.

Aoife Dillon
Fera Science Limited

Under the UK's 25 Year Environment Plan, published in 2018, the UK government committed to "Putting Integrated Pest Management (IPM) at the heart of a holistic approach, by developing and implementing policies that encourage and support sustainable crop protection with the minimum use of pesticides". One mechanism designed to support this plan is Defra's Sustainable Farming Incentive (SFI) Standard on IPM, published in 2023, which included payment for specific actions related to IPM planning, improving habitat for natural enemies and decreased pesticide use. In this talk we will discuss two recent surveys which looked at how IPM, and biopesticide use, are currently viewed and what changes could be made to drive better adoption. The first survey was commissioned by Fera and included feedback from biopesticide manufacturers, advisors, and end users, while the second survey focused on farmers as was generated under the Test and Trials programme run by the NFU, ADAS and SRUC. Results of both surveys will be presented, including progress on delivering support tools and how changes in payments under the new SFI programme are expected to affect uptake.

IPM of Cotton: A ray of hope in Pakistan

Shafqat Saeed, Naeem Iqbal, Muhammad Nadir Naqqash, Muhammad Asif Farooq, Farrukh Baig
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Corresponding Author: shafqat.saeed@mnsuam.edu.pk

The survey team of MNSUAM visited 860 cotton farmers throughout the cotton belt of south Punjab, inquired about the reasons for the success/failure of cotton, and analyzed the data. According to the cotton survey 2022, 96% of respondents agreed that the Agriculture Department conveyed cotton production and protection technology in time, and farmers benefitted from the Government advisory. The first step of the advisory was to avoid insecticidal spray for two months, which was confirmed by 82% of farmers. The other advisory was the use of biopesticides, and 85% of respondents got information regarding the application of biopesticides. Among the major insect pests, farmers applied pesticides for whitefly (65%), jassid (46%), and thrips (23%). According to the farming community, the most harmful factors for the reduction of cotton were weather (97%), insecticides (13%), poor quality seed (31%), and insect pests (17%). About 87% of respondents reflected that beneficial insect played an important role in managing the sucking insect pests below ETL level, where they did not spray insecticides in the first two months of cotton sowing. Until October 2022, approximately a 16% reduction in the insecticidal spray was recorded compared to last year, which positively reduced farmers' input cost/acre. The average expenses were Rs. 24362 and Rs. 25989 for fertilizer and Rs. 9389 and Rs.7420 for pesticides, with an average yield of 13 and 24 mounds per acre in non-IPM and IPM fields, respectively. The results suggested that adoption of IPM model throughout the cotton zone can be very helpful to boost the yield and Pakistan's economy.

Keywords: Cotton, Eco-friendly Pest Management, Farmers' survey, Pesticide Reduction

Biocontrol application and monitoring of *Beauveria bassiana* in China

Chengshu Wang

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The biocontrol agents have been well developed and applied in large scales in China. Dozens of products developed from *Metarhizium* and *Beauveria* species have been registered for the control of agriculture, forest, tea and or green house insect pests. In particular, it is one of the largest biocontrol programs in China or even worldwide to use *Beauveria bassiana* to control the forest insect pests such as the Masson's pine caterpillars *Dendrolimus* spp., which has been obtaining the sustainable and eco-friendly biocontrol efficacies. To monitor the persistence of released strain in local environments, we conducted the long-term collections of *B. bassiana* strain from the released place at different seasons for more than 20 years. The following genome resequencing and population genetics studies revealed that *B. bassiana* population was largely clonally reproduced in the environments. The population genetic diversity varied between seasons with the features of frequent host jumping, isolate migration and strain/genetic exchanges between populations. It is of particular importance to find that the industrial strain released for insect pest control could persist in the field 20 years post application. Similar to the enzootic occurrence of local strains, the release strain could infect non-target hosts at a low frequency and did not displace the local populations. It was also found that the cryptic sexual reproduction might also occur in the fields. The data provide solid evidence to support the sustainable control effect of mycoinsecticides. For different species of biocontrol agents, environmental monitoring is still required to help understand the nature and features of fungal adaptation to diverse environments.

Current and future pests of honeybees and their control, and honeybees as biomonitors.

Norman L Carreck
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Honeybees suffer from many pests and diseases, the most serious being the varroa mite, but other exotic threats loom, notably the yellow legged Asian hornet *Vespa velutina*, which has been frequently sighted in the UK in 2023, but also the small hive beetle *Aethina tumida*, now present in Italy, and the *Tropilaelaps* mite, spreading from Asia into troubled areas such as southern Russia and possibly Ukraine. IPM approaches will play an increasingly important role in the control of most of these pests. Honey bees themselves are effective biomonitors of the environment through their foraging activities, and the INSIGNIA-EU project: https://www.insignia-bee.eu/ is currently using citizen scientist beekeepers in all 27 EU countries to use their hives to monitor for various kinds of pollution.

Lure development for the stored legume pest, Acanthoscelides obtectus

J. Vuts

Protecting Crops and the Environment, Rothamsted Research, Harpenden, AL5 2JQ, UK

The dried bean beetle, *Acanthoscelides obtectus*, is an economically important pest of stored legumes worldwide. Tracking the human-aided dispersion of its primary hosts, the Phaseolus vulgaris beans, it is now widespread in most bean-growing areas of the tropics and subtropics. In temperate regions where it can only occasionally overwinter in the field, *A. obtectus* proliferates in granaries, having multiple generations a year. Despite its negative impact on food production, no sensitive detection or monitoring tools exist, and the reduction of local populations still relies primarily on inorganic insecticides as fumigating agents. However, in the quest to produce more nutritious food more sustainably and healthily, the development of environmentally benign crop protection methods is vital against *A. obtectus*. Because *A. obtectus* is a generic pollen and nectar feeder, we adopted an electrophysiological (EAG) screening approach, using the antennae of females, to identify physiologically active, volatile phytochemicals, which could then be investigated for their attractiveness in laboratory behavioural assays and preliminary field tests. Of the twenty-seven compounds tested in EAG screening, five compounds, i.e., methyl anthranilate, methyl eugenol, benzyl alcohol, (RS)- lavandulol and 2-phenylethanol, elicited stronger EAG responses than the standard (1-phenylethanol). In four-arm olfactometer bioassays, female *A. obtectus* preferred the olfactometer arm containing the odour of either methyl anthranilate or benzyl alcohol compared to the solvent control. In preliminary field tests using these two compounds in a binary mixture, at least five times as many beetles were caught on baited traps compared to non-baited traps. The field data also suggested that benzyl alcohol was primarily responsible for the field activity of the blend. We hypothesize that the attraction of *A. obtectus* to the combined benzyl alcohol/methyl anthranilate and the single benzyl alcohol baits is connected to the species` nectar and pollen-feeding behaviour and not to its intraspecific communication. Current field trapping trials are testing the addition of further compounds to the benzyl alcohol bait to increase its attractiveness at a European and South American location.

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Combined strategies to promote multi-trophic interactions in biocontrol

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Increasing willingness to reduce the use of conventional insecticides correspond to an urgent need for efficient alternatives to control pests and associated diseases for viral vector groups such as aphids. A broad range of mobility and feeding behaviors are driven by signal cues in and/or around crop plants both for pests and entomophagous beneficials. Food webs in a diversity of processes in agroecosystems should then be considered to understand multitrophic interactions and lead to efficient biocontrol strategies. These relations also involved plenty of micro-organisms associated to plants and insects and need to be more increasingly investigated. Considering several plant – pest models, a broad range of interactions between micro- and macro-organisms were found and revealed effects from synergy to symbiosis or incompatibility to pathogenicity. The development of resistant crop varieties and the use of plant volatile organic compounds (VOCs) have to include pests and further trophic levels with predators and parasitoids to develop attract and kill, attract and infect or push - pull strategies. Direct toxicity of entomopathogenic fungi (EPF) to pests have to correspond to innocuity to useful entomofauna while endophytic fungal behavior in crop plant should be validated for biocontrol considering multitrophic levels. Also, soil bacteria can be particularly effective because they induce systemic resistance (ISR) as Plant Growth Promoting Rhizobacteria (PGPR). Different crop - pest models were investigated to illustrate applications of a variety of biocontrol opportunities and compatibilities including micro- and macro-organisms. This contributes to propose technical itineraries for comprehensive approaches to control pests depending on particular situations.

Seeing disease vectors from the sky: How far can we go?

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Emerging zoonotic diseases have become a pressing global concern, with a notable rise in their incidence worldwide. Among the critical contributors to this surge, vector-borne diseases play a significant role. Various factors, both global and local, have been identified as drivers of this change, encompassing the ever-shrinking world due to globalization, the relentless impact of climate change, human-induced alterations in land use and cover, as well as socioeconomic disparities and policy decisions. Addressing this challenge necessitates precise knowledge of the distribution, abundance, and spread of disease vectors and the diseases they transmit. However, traditional field surveys are characterized by high labor intensity and costs, necessitating alternative methodologies to overcome these challenges.

This presentation proposes an innovative approach that combines strategic sampling and spatial modeling with co-variate data to reduce the financial and labor burden associated with field surveys. By harnessing the power of remote sensing and advanced modeling techniques, this methodology contributes to provide valuable insights into the dynamics of vector-borne diseases, empowering effective and informed decision-making in disease management and prevention. The significance of this approach is exemplified through the case study of the tiger mosquito's spread in Europe. The tiger mosquito (*Aedes albopictus*) is an invasive species known to transmit diseases such as dengue, chikungunya, and Zika viruses. Analyzing its expansion in Europe illustrates the potential of the proposed methodology.

We will first delve into the fundamental aspects of what needs to be mapped concerning the distribution and movement of disease vectors, along with the associated pathogens. Subsequently, we will explore how satellite imagery and remote sensing technologies can effectively contribute to reducing the laborious sampling efforts. These state-of-the-art tools offer a cost-effective means of obtaining spatially explicit data, thereby assisting in the identification of high-risk areas for vector-borne diseases. Furthermore, we will highlight the role of spatial modeling in understanding the behavior of disease vectors. By incorporating relevant co-variate data, such as environmental factors and climate patterns, these models can contribute to predict the spatial and temporal dynamics of vector populations. They offer critical insights into the timing and intensity of vector activity, thereby enabling more proactive and targeted control measures. Finally, throughout our talk we will emphasize how important it is to keep taking into consideration non-environmentally related drivers that may affect risk at a more local scale.

In conclusion, this presentation highlights the urgency of addressing the global rise in emerging zoonotic diseases, particularly vector-borne diseases. The proposed approach of combining strategic sampling, spatial modeling and remote sensing, when combined with a good knowledge of the drivers of local change is becoming one of the cornerstones of vector-borne disease surveillance and management. By providing a cost-effective, data-driven, and predictive framework, this methodology offers a promising avenue to mitigate the impact of vector-borne diseases on human health and well-being.

Endophytic biocontrol fungi, Chitosan and VOCs for IPM

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Integrated Pest Management (IPM) still holds many unexplored resources to increase its efficacy in commercial crops. Insect and nematode antagonists such biocontrol fungi (BCA) are key components of IPM.

The Nematophagous Fungus (NF) *Pochonia chlamydosporia* (Pc) infects eggs of plant parasitic nematodes worldwide. Pc induced soil suppresiveness to plant parasitic nematodes was first known in extensive (cereal) crops. Recently, soils suppressive to root knot nematodes have been found in intensive (horticultural) crops in NE Spain. Entomopathogenic fungi (EF) can, in turn, cause epizootics reducing insect pest damage to crops. Applying conidia of *Akantomyces* or *Beauveria* local strains, we have significantly reduced scale insect or red palm weevil damage to lemon trees or to palms, respectively, in SE Spain. In both cases EF multiplied in the field since epizootics spread to untreated plots. BCA inoculum can therefore withstand and multiply under harsh environmental conditions. NF and EF are both multitrophic BCAs. They colonize, as true endophytes, crop plants paramount for food security and resilience to global change (eg. Cereals, date palms or banana). This is reflected in the genome and biocontrol strategy similarties between Pc (NF) and the widespread (EF) *Metarhizium* spp. Pc acts as a mutualist colonizing root cells but preserving their plasma membranes. For Pc Jasmonic Acid (JA) perception seems to regulate fungus colonization of plants. The fungus promotes plant growth and development, leading to earlier flowering and larger yield in food security crops such as tomato. BCAs can therefore be applied as biofertilizers solving eutrophication problems caused by mineral fertilizers.

Chitosan, a deacetylated form of chitin, can be obtained at low price from seafood waste, solving ammonia pollution in sea farms. It is non-toxic to humans and other non-targets. The polymer generates ROS stress in plants and fungi. This produces oxylipins derived from lipids (just like JA) and other VOCs. Chitosan irrigation, at moderate doses, induces plant hormones and defenses. Root exudates from chitosan-treated plants inhibit root pathogenic fungi and nematode hatching. Pc and EF are resistant to chitosan for their low fluidity membrane and cell wall enriched in beta 1-3 glucans. Conversely, fungal pathogens such as Fusaria wilt of tomato and banana are inhibited or killed by chitosan. Chitosan enhances Pc appressorium development and promotes subsequent root knot nematode egg infection.

Insect and nematode pests, share common environmental defences like chitin-protein barriers. Chitin is a molecular pattern recognized by crop (and pest) immune systems. BCAs have coevolved with their hosts and circumvented their defences. Chitosan is also endogenously produced from chitin by Pc and EF. We believe this is a strategy of these BCAs to avoid plant immunity. Chitosan oligomers are not well perceived by plant membrane receptors, unlike chitooligosaccharides. Fungal pathogens and BCAs secrete LysM effectors for shielding chitin from plant defence chitinases. Pc encodes LysM effectors different from those of fungal plant pathogens. This may be another method of crop Immunity modulation by BCAs.

Concluding, IPM can therefore benefit from multitrophic biocontrol agents which enhance plant growth, defences and yield. Some biocontrol fungi are compatible with chitosan which elicits plant defences and BCA pathogenic determinants including bioactive VOCs. These volatiles can prime crops against pathogens or act as insect pest repellents. These are rather unexplored components of push and pull strategies. Therefore, Endophytic Biocontrol Fungi, Chitosan and VOCs which be used for new IPM strategies.

Evaluation of UAS imagery to monitor crop productivity and effectiveness of bioprotectants.

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UAS provides data and information on crop performance and health that can be comparable to expert in field inspection. UAS inspection can be scaled easily and therefore potentially provides a highly cost effect means of monitoring crops. We describe applications of UAS based remote sensing in research and breeding contexts, with examples from potatoes, oats and the biomass crop Miscanthus. Late blight (Phytophthora infestans) of potato crops necessitates regular prophylactic spraying with biocides in the UK and many other moist climates. This contributes to significant agrochemical consumption under commercial production scenarios. As many control agents are being withdrawn due to environmental and health concerns and blight-resistant cultivars are not yet accepted by most growers, there is an urgent need to assess the effectiveness of novel treatments rapidly and objectively, including bioprotectants. For this, we used two different approaches for their ability to provide useful proxies for reduction in disease progression in foliage and for preservation of yield. Mini plots of potatoes were grown, treated regularly with experimental sprays or a widely used commercial fungicide, Mancozeb, which is about to be withdrawn. Plots were inoculated with locally prevalent strains of P. infestans. Disease progression was assessed at regular intervals both visually and by drone-based photogrammetry and related to metabolite profiles and final yield.
Similar drone-based assessments of other crops were undertaken in a breeding context, where its it critical to identify high performing genotypes from large breeding populations.
Our results indicate that simple vegetation indices based on drone acquired RGB images could be significantly correlated with the harvested yield, and in the case of potato the imagery accurately reports plant health. Therefore, we conclude that time-stamped images acquired across the growing season using a standard RGB camera mounted on a standard drone provides a useful proxy for plant performance the effectiveness of protective treatments.

Microbial pest control is taking new shape by novel tailored formulations and harnessing of more ecological attributes.

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Biological pest control is a highly sought after alternative to conventional pesticides. Microbial control agents (MCA), also known as microbial biopesticides are microorganism-based, low risk, environmentally friendly. Yet, the challenge to achieve pest control at field conditions lies in the ability to develop a promising venue to employ MCA successfully at unfavorable conditions. In this communication two major empirical strategies aimed at increasing MCA efficacy and outdoor performance are presented: (i) novel environmentally protected formulation and (ii) realizing the broader ecological attributes of MCA application. The development of novel formulation, aims at increasing the performance of the MCA, is consisted of nanoparticles stabilized Pickering emulsions and considered novel in agrochemistry. It enables several critical specifications among which are UV absorbance, water retention, dispersion. One attractive possibility arising from the accumulated evidence, is that, in addition to their direct activity against insect pests, MCA such as bacteria and fungi may induce systemic plant immunity and disease resistance by directly activating the plant host defense machinery. Hence, protecting EPF from adverse conditions by the incorporation of EPF in plants as endophytes, has emerged as a promising alternative approach for a pest control strategy overcoming the constraints of environmental conditions. The combination of both strategies upgrades the microbial pest management and may lead to a wider and augmented use of MCA against challenging pests.

NEW IPM 2023

Seeing the unseen: optimising biological crop protection through hyperspectral imaging.

Anthony Surrage

Fargro Limited, Vinery Fields, Arundel Road (A27), Poling, Arundel, West Sussex, BN18 9PY

The talk will discuss the ground-breaking integration of hyperspectral imaging technology within an IPM programme in modern horticulture. In the face of the many headwinds the industry faces, early detection of pests and diseases is paramount. This talk will illuminate how hyperspectral imaging, when synergised with real-time environmental conditions, provides presymptomatic detection of threats, allowing growers to understand risk more accurately. More than merely identifying problems, this unified approach empowers growers to transform data into automated action through a knowledgebase, generating precise and timely advice. This alignment not only optimises the efficacy of biological crop protection inputs but also bridges the gap between technology and actionable insights, reducing waste and enhancing yield. An in-depth examination of the systems, its real-world applications, and future prospects will offer attendees a comprehensive understanding of a pioneering method poised to reshape sustainable horticulture for more robust IPM programmes.

The advent of entomopathogenic ascomycetes as multipurpose microorganism for crop protection and production

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A key challenge for entomopathogenic ascomycetes (EA) to be increasingly adopted by farmers is the exploitation of their multiple lifestyles as valuable multipurpose plant-beneficial microorganism for sustainable agriculture. An increasing number of recent studies have shown that EA, often considered only as insect pathogens, play additional roles in nature mostly based on their multifaceted interactions with the plants. Indeed, in the colonization of plants as endophytes or rhizosphere competent microorganisms, several EA species have evolved the capacity to communicate with the plant and produce numerous benefits to its host. These important attributes have been probably overlooked in the quest to develop fungal entomopathogens as microbial control agents exclusively against arthropod pests, whereas they may possibly offer opportunities for multiple uses in crop production and protection. Aside from the protection of the plant against biotic stresses such as pest and diseases, other benefits of endophytic and rhizosphere competent EA in improving the plant response to abiotic stresses such plant nutrition, drought resistance etc. and even plant growth promotion effect have been reported. Evidence is hereby given on the potential of EA as direct and indirect biocontrol agents, on their compatible multitrophic interactions, but also on enhancing plant growth and inducing immunity and resistance to other biotic and abiotic stresses, which are useful multifunctional properties for pest control and crop production. On the overall, EA arise as multipurpose, plant-beneficial microorganisms for sustainable protected cultivation and even the present legislative framework might also accommodate the demonstrated evidence of entomopathogenic fungi proficiency as a plant-beneficial microorganisms contributing towards eco-sustainable agriculture.

Remote observation in crop pests and disease monitoring

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This talk will give an overview of remote detection of crop pests and disease, through a range of examples considering monitoring scales from UAV to satellite. The potential for early detection of visual and pre-visual indicators of plant disease is assessed. Key current research topics include the role of models in linking remote measurements to plant level manifestation of symptoms, and ability of recently available measurements such as solar induced fluorescence (SIF). Finally open questions and recommended research topics are presented for discussion.

Multifaceted entomopathogenic fungi: Improving the fungi-based products activity against pests and diseases of crops

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In the wark will be presented new data on the host-parasite interactions in the entomopathogenic fungi (EPF) -pest systems, as well as the evolution of insect resistance to fungi. Some ways to improve the effectiveness of fungal biopreparations will be demonstrated. Current developments in the genetic transformation of entomopathogens, the use of RNA interference, nanoparticles, insect hormones and their analogues will be considered as strategies to increase the activity of EPF. Fungal preparations based on EPF (mycelial and conidial formulations) have been tested on potatoes in the field conditions of the Siberian region as biofertilizers. In this work we present as EPF effects on the growth and development of potato plants, soil microbiota, plant physiology and resistance to diseases.

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Monitoring Airborne Plant Pathogens to improve crop protection

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IPM is important to secure food production and reduce GHG-emissions by preventing losses to disease. A range of monitoring and surveillance approaches are possible, including imaging (from satellites, aircraft or in-field sensors), visual observations, portable diagnostic tests, weather-based models and airborne inoculum detection. Many important crop diseases are spread by airborne spores, some of which blow hundreds of miles to infect crops down wind, although some only remain viable for shorter distances. Air sampling provides an excellent early warning of imminent disease for these airborne plant diseases to optimise application of CCPs, especially where samples can be assessed very quickly or where there is a long disease incubation period, allowing sufficient window of opportunity for CPPs to be fully effective. Detection of airborne inoculum can greatly improve the timing of both biologicals and fungicides and so can reduce the development of fungicide resistance if products are used more sparingly and only at optimal times.

Automated detection systems are in development to avoid delays in sending samples to a lab for testing, which is particularly advantageous where very rapid disease development occurs e.g. potato blight. Methods under investigation include image-based identification of captured spores and integration of air sampling with automated immunological and DNA-based assays. Samples can also be taken either on a static site or a mobile platform such as a car or drone. An advantage of DNA-based detection is that with appropriate primers, it is possible to detect fungicide resistance and deploy alternatives. Wireless communications and deployment as a network will make information from air samplers timely and more robust. The type of air sampler and where it is used are important considerations due to effects on results caused by the volume of air sampled, collection efficiency of the device, height above ground level and proximity to crops.

Entomopathogenic fungal-plant interactions: an ecological approach to sustainable pest management

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Entomopathogenic fungi (EPF) have become a valuable tool in Integrated Pest Management to directly reduce crop pests. However, these fungi can also colonize plant tissues as endophytes and cause indirect effects on the herbivores by altering plant defense responses. Therefore, understanding the reciprocal effects of EPF and herbivores is essential to uncover indirect plant-fungus-herbivore interactions. Our research focuses on (1) whether inoculation of tomato plants with EPF can increase tomato resistance against spider mites (2) whether these effects act synergistically with the effects of other beneficial fungi or with resident soil microbes, and (3) what role plant secondary metabolites play in mediating such microbe-insect interactions. We show that EPF enhances tomato resistance to spider mites, but that these effects can be mitigated by resident soil microbes. Co-inoculation with other beneficial plant fungi (arbuscular mycorrhizae and mycoparasitic fungi) showed additive effects of dual inoculations that disappeared in full fungal mixtures. The studied secondary metabolites (phenolics and flavonoids) were unlikely to mediate the observed interactions. Furthermore, the study delves into the effects of EPF on plant growth promotion, providing valuable insights for maximizing their efficacy and potential commercial applications. Understanding the mechanisms underlying the impacts of fungal endophytes on pest resistance and growth promotion is critical for ensuring their successful implementation in agricultural practices.

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How the evolution of secondary metabolism affects the lifestyle of endophytic entomopathogenic fungi: the case of *Metarhizium brunneum*

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Fungi are lower eukaryotes known for their diverse modes of life which extend from saprophytism and decomposition of dead matter to parasitism, mutualism and commensalism. Many species are known for their variable interactions with plants, animals, bacteria, and other microbes, as the majority of them are either parasites or endosymbionts. A big question which has not yet been fully addressed is how fungi adopted these lifestyles through evolution. The last few decades, with the advancements of molecular genetics and genomics, it became evident that fungi have the arsenal of genes which allow them to employ different lifestyles. An excellent paradigm of this plasticity is the genus *Metarhizium*. All species of this genus are well known as entomopathogenic and furthermore, they have been employed as Biological Control Agents for the protection of plant crops. Nowadays, many studies have shown that *Metarhizium* can also survive endophytically in a variety of different plants and thus, they examined the fungal metabolic pathways and genes involved in endophytism, in order to deploy them as biofertilisers and biostimulants. From the evolutionary aspect, the question is which mode of life of this fungus preceded the other: entomopathogenicity or endophytism?

For providing a probable answer to this question and since the whole genomes of several species of this genus are available, it is imperative to investigate their gene content and functions. An emphasis is given to genes and their products involved in metabolic pathways of the secondary metabolism, as this kind of metabolism while not crucial for the survival of the organism, it offers many advantages for the organism's adaptation to their environment. A comparative analysis of the known genomes for their diverse biosynthetic gene cluster (BGCs) and their Protein Coding Genes (PCGs) showed that these metabolic genes organised in clusters may divided into three different categories, i.e., common BGCs to all genomes even from close relatives with other modes of life, scattered BGCs to random genomes and unique BGCs for certain species of the genus only. Moreover, it became obvious that in few cases, several auxiliary PCGs, but still crucial for the metabolite production of the BGCs, were shared among two different BGCs.

If the above are taken into consideration, the prevailing theory that plant host colonisation preceded entomopathogenicity cannot be ruled out, since major secondary metabolites of *Metarhizium* like destruxins, can also be found as products in phytopathogenic species like *Alternaria alternata*. However, the existence of a gene of polyketide synthase in *Metarhizium* and not in the genomes of its close entomopathogenic relatives indicate Horizontal Gene Transfer events for obtaining metabolites which will help the carrying organism to adapt afresh in a plant, as endophyte this time. The presence of conidia in the soil and thus, the availability of *Metarhizium* to penetrate plant host is an extra argument for adopting the endophytic lifestyle. Overall, further in-depth analyses are needed to conclude which evolutionary route the fungi followed and what to expect in the future for the lifestyle changes of fungi.

Integrated Pest Management and sustainability: why developing metrics is important?

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Integrated Pest Management (IPM) is the strategy that combines pest management techniques looking to reduce pesticide use within agricultural production systems and forms a critical component of sustainable agriculture. IPM integrates several approaches to prevent pests entirely or reduce them to acceptable levels, a system designed to be sustainable environmentally and economically.

Within the EU, focus on sustainability is very high on the political agenda and of increasing importance. The European Green Deal and the Farm To Fork strategy establishes a number of goals focusing on sustainable food production to be reached by 2030 for EU member states, among which the target to reduce the use of chemical plant protection products by 50%. This brings new crop protection challenges for our farmers, increasing the need for more innovative and sustainable solutions in the future.

But how can we measure the sustainability of crop production in general and more specifically of IPM? There are a few 'scattered' and non-harmonized models at international level developed mostly in recent years. The establishment of sustainability metrics and their correct use can facilitate: (i) assessing environmental targets; (ii) monitoring progress towards targets and assessing the effectiveness of strategies; (iii) benchmarking and fairness, which relies on transparency; (iv) communicating progress to stakeholders.

Generally, it is clear that there is a need to develop sustainability metrics that are reliable, harmonized and internationally agreed. The awareness for their need is rapidly growing. However, the existing lack of standardized metrics and methods for verifying environmental sustainability claims still reduces their credibility. Implementing more comprehensive IPM and pesticide metrics remains a key target for us, as it will facilitate benchmark current crop protection practices and monitor progress of sustainability when practices change.

NEW IPM 2023

Unveiling Genomic Diversity in Entomopathogenic Fungi: Insights from Comparative Analysis of *Metarhizium brunneum* strains

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Entomopathogenic fungi (EPF) belonging to the Order Hypocreales are widely known for their ability to infect and kill insect hosts. Many of these fungi, including members of the genus Metarhizium, exhibits a remarkable ability to adapt to other ecological roles. They can be found as saprophytes, rhizosphere colonizers, and endophytes, promoting plant growth and resistance to pests and diseases. Understanding the underlying genetic and molecular mechanisms governing these diverse interactions is pivotal, given their potential to be exploited as biocontrol agents and biofertilizers. However, several genes, as well as metabolic pathways that allow this versatility, have not been determined in-depth yet. Recent advancements in whole genome sequencing methodologies have facilitated a deeper understanding of the multifaceted functions these fungi perform within natural ecosystems, thereby expanding their potential applications. In this work, a newly sequenced, high-quality genome of one of the most virulent EPF strains, *Metarhizium brunneum* V275 (commercially known as Met52) is presented, assembled through the combination of nanopore long and Illumina short reads. The assembly and annotation pipeline detected an extensive gene and protein repertoire, utilizing a combination of homology and ab initio methods. In order to explore genetic variation and differences in entomopathogenic and endophytic behaviour among EPF strains, a comparative genomic analysis was performed with another highly effective EPF strain, *M. brunneum* 4556, and other publicly available genomes of Metarhizium species. Functional annotation results confirmed that EPF genomes are versatile with respect to their gene content and structure. Further analyses showed an abundance of Transposable Elements (TEs), with strain-specific genomic variations. Emphasis was given to the prediction of the Secondary Metabolic (SM) compounds produced by these strains, as they are key determinants of successful host colonization and niche diversification. Results revealed that all strains employ a broad metabolic repertoire, with many SMs being organized in Biosynthetic Gene Clusters (BGCs), some of which have unknown functions that need to be determined. Overall, comparative genomic analyses among these strains provide valuable insights into the genetic basis of EPF's versatility, their dynamic genomic organization as well as their evolution. In addition, they can showcase the potential of EPF strains as insecticidal, antifungal, or plant growth-promoting agents.

Keywords: entomopathogenic fungi, Metarhizium brunneum, whole genome sequencing, comparative genomics, secondary metabolites, genetic diversity.

Assessment of two endemic soil-borne entomopathogenic fungi, *Metarhizium brunneum* and *Metarhizium majus* in a multitrophic interaction context to control beet mild yellowing virus

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Sugar beet is an economically important crop particularly threatened by the aphid *Myzus persicae* (Sulzer 1776), vector of the beet mild yellow virus (BMYV). As neonicotinoids soon will be completely forbidden throughout Europe, the yellowing virus will increase as a major problem for this crop production industry. The use of microbial control within the ecological network concept is of great interest to investigate the efficiency of soil-borne entomopathogenic fungi (EPF) against insect pests and their borne diseases. The performance of EPF is continuously jeopardized by multiple layers of interactions between the environmental factors where they will be applied, the host plant, the insect pest and the virulence against beneficial insects. Here, we provide a first-line evaluation of the potential of two endemic EPF strains *Metarhizium brunneum* and *Metarhizium majus* to colonize sugar beet plants, on fitness of the vector pest *M. persicae* and transmission of BMYV. A preliminary insight on the impact of the fungal treatment on the beneficial insect, *Episyrphus balteatus* (De Geer 1776) is also highlighted. Exploring the potential of both endemic fungal species within a multitrophic cascade effects at cross-kingdom level are of utmost importance to design new efficient microbial control strategies against aphids.

Entomopathogenic fungi contributing to sustainable crop production through non-entomopathogenic roles

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Hypocrealean entomopathogenic fungi (EPF) such as *Beauveria bassiana* and *Metarhizium* spp. are pathogenic to several crop pests and multiple commercial formulations of these fungi are used as biopesticides in IPM programs against those pests. These soilborne fungi not only infect their arthropod hosts but also have a relationship with plants and interact with other microorganisms in the crop ecosystem. They endophytically colonize plant tissues and negatively impact herbivores through antibiosis, form mycorrhiza-like relationship with plant roots and improve water and nutrient intake, and protect plants from plant pathogens. Multiple studies were conducted in California exploring the non-entomopathogenic roles of some commercial and local isolates of EPF. Impact of EPF on twospotted spider mite (*Tetranychus urticae*) and green peach aphid (*Myzus persicae*) infestations in strawberry, drought tolerance in cabbage, *Fusarium oxysporum* f.sp. *vasinfectum* infection in cotton, and charcoal rot by *Macrophomina phaseolina* in strawberry will be discussed.

Biocontrol at the Root Level: Unraveling the Mechanisms of Metarhizium brunneum in Protecting Oilseed Rape from Soil-Borne Pathogens

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Metarhizium brunneum, a fungal entomopathogen found in soil, can establish associations with plant roots. Existing research has shown that the colonization of roots by beneficial fungi can directly influence soil-borne pathogens through competitive and antibiosis mechanisms. These fungi can also trigger systemic responses in plants, preparing them for more rapid and robust reactions to stressors. However, the precise mechanisms through which *Metarhizium* inoculation mitigates symptoms caused by plant pathogens remain largely unknown. In this study, we assessed *M. brunneum* potential to safeguard oilseed rape (*Brassica napus* L.) plants from the soil-borne pathogen *Verticillium longisporum*, investigating whether the observed effects stem from direct interactions and/or plant-mediated responses. Through in vitro and greenhouse experiments, we examined fungal colonization of the rhizosphere and plant tissues, alongside targeted gene expression analysis to evaluate plant responses. The findings indicate that *M. brunneum* can delay the colonization of plant root tissues by the pathogen, leading to decreased disease symptoms. The study revealed that direct competition and antibiosis mechanisms are at play; *M. brunneum* growth in the soil was promoted by the pathogen and the entomopathogen inhibited the in vitro growth of *V. longisporum*. Employing a split-root setup, we demonstrated a plant-mediated effect, with improved plant growth and reduced disease symptoms observed when *M. brunneum* was present in the systemic compartment. Additionally, the split-root setup highlighted that *M. brunneum* alters the plant's response to the pathogen by locally activating essential defense hormones within the salicylic acid (SA) and abscisic acid (ABA) pathways. Furthermore, a stronger systemic induction of the *PR1* gene suggested a priming effect involving the SA pathway. Overall, this study provides insight into the mechanisms behind *M. brunneum* protective effects against soil-borne pathogens in oilseed rape plants, underscoring the potential of this fungal entomopathogen as a biocontrol agent in sustainable agriculture.

Assessing the sustainability of IPM: towards a new model to face the challenges.

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While sustainability has become perhaps the most common word in scientific research and in policy evaluation, its assessment remains very difficult in most field and, among these, in the agricultural and agri-food sector.

The broad agreement about the three main areas of sustainability (environmental, economic and social sustainability) is not sufficient to identify clearly which specific aspect or variable we should evaluate to assess and compare sustainability of different technological solutions.
In the agricultural sector, in particular, IPM has been developed many decades ago with two different goals: reduce possible negative effects of excessive use of pesticides, on one side, and cost optimization of pest control, on the other.

More recently, few attempts have been made to evaluate sustainability of different agricultural technologies and different IPM solutions. The evaluation has been made, in general, with reference to key environmental variables that are measurables and more easily comparable, and to production, in terms of quantity.

In this contribution we present a model developed with the aim of comparing sustainability of different agricultural technologies, and therefore different IPM solutions; the model includes what are believed to be the key aspects of economic and social sustainability. The challenges faced by this model include the selection of all relevant key variables, on one side, and the definition of a way to find the optimal solution on the other. A proposal is presented to make a step forward in the direction of and increased sustainability of agricultural production.

Push-Pull - a novel strategy for pest management in protected crops

Dr Nayem Hassan, Dr Clare Sampson, Dr Abu Imroz Ali, Koteswararao Chiluveri, Rharles Griffiths

Russell IPM research and development team has developed a novel pest management strategy, PUSH-PULL, which exploits naturally occurring semiochemicals to modulate pest behaviour. This strategy incorporates both repellent and attractive mechanisms to limit pest infestations and enhance the presence of natural enemies within protected soft fruit production, thereby contributing to Integrated Pest Management (IPM) approaches. The strategy encompasses two core components; push using naturally occurring Phenolic Compounds (PC) produced by plants in response to insect attacks, pests are deterred from infesting areas with high PC concentrations. On the other hand, natural enemies are attracted to these compounds, leading to increased predation and reduced pest populations. The Pull strategy utilizes colour and scent cues to attract pests into traps. Species-specific pheromones are incorporated into traps to maximize pest attraction and capture.

The study highlights the use of specialized traps called Optiroll Plus, which have been effective in reducing pest numbers. The efficacy of the PUSH-PULL strategy was assessed through field trials conducted in strawberry and blueberry crops. In strawberry cultivation, the implementation of tailored blue sticky roller traps infused with thrips pheromones, alongside the application of MagiPal, led to a notable 50% decrease in thrips populations and a remarkable 70% reduction in capsid-related damage. Similarly, in blueberry fields, the push-pull approach employing white roller traps infused with blueberry midge pheromones and MagiPal resulted in a significant 65% reduction in midge larvae per shoot and mitigated shoot damage by 28%. Similar trend was found when controlling *Tuta absoluta* in greenhouse using push pull and application of *Metarhizium brunneum, V275* on the ground to reduce pupal population. It has been resulted over 90% control of *T. absoluta* infestation in tomatoes in Portugal.

In summary, the PUSH-PULL strategy demonstrates promise as an innovative and sustainable pest management paradigm. By harnessing ecological cues and naturally occurring compounds, this approach proves efficacious in controlling pest populations and minimizing crop damage. Particularly in systems reliant on natural enemies for pest control, this strategy offers a pragmatic value for reducing dependency on chemical interventions.

Towards the ecological and digital transition in integrated pest management: remote monitoring of the olive fruit fly and its microbial control.

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The transition in agriculture towards an ecological and smart approach is one of the main pillars of the European Green Deal. Tephritid fruit flies pose significant constraints on fruit production worldwide. These pests attack the harvestable part of the plant during critical periods of crop growth, causing cutaneous damage, as seen in the case of the olive fruit fly, *Bactrocera oleae* (Rossi) (Diptera: Tephritidae). Therefore, optimizing monitoring and integrated management practices can guarantee more efficient and cost-effective decision-making, allowing for timely interventions when dealing with such agricultural challenges. In this work, two years field trials in Andalusia (Spain) were carried out to optimize trap model, color, and size, together with the trap density, to accurately determine pest spatial distribution and damage curve as a function of the olive cultivar. Among the six trap models selected, Mcphail and yellow sticky traps outperformed the other four models for fly monitoring, whereas Mcphail traps caught the higher number of natural enemies. Therefore, the sticky trap model was selected to unravel the effect of the colour on both pest and natural enemy catches, with the yellow one outperforming the white, green, and blue in pest monitoring with lower impact on natural enemies. Regarding yellow sticky trap catching surface, even if 20x25 and 10x25 cm single-size traps were equally efficient for olive fly monitoring, the large double-sided yellow sticky trap catches significantly more natural enemies than the small double-sided trap, a key result for developing a less-costly and environmentally friendly monitoring system. On the other hand, for the six selected olive varieties, it was demonstrated the cultivar-based shape of the damage curve. Finally, it was determined that 15 traps per hectare optimized the estimation of the pest spatial distribution. Finally, a prototype of electronic trap and a set of electronic services were developed and presented to the sector. Additionally, the soil application of the entomopathogenic fungus *Metarhizium brunneum* on a wide-area scale was integrated with the digital monitoring system to further achieve the objectives of IPM. On the overall, the present research provides key information for new trap design and olive fly forecasting and IPM development.

Keywords: Tephritidae, Bactrocera oleae, smart monitoring, electronic traps, electronic services

Visual modelling to optimize pest capture on sticky traps

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Commercial sticky traps typically rely on trial and error to establish which colors are most attractive to target pests. Using visual modeling however it is possible to predict how colors may be perceived by pests, allowing for the design of traps to maximally target crop pests. Previous work has shown that visual modeling of blue colors to improve visual stimulation improves catch of western flower thrips. Following these methods, we are establishing whether similar modeling can improve colluded sticky traps for other crop pests such as glasshouse whitefly.

Developing new Integrated Pest Management (IPM) strategies against wireworms using volatiles organic compounds

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Wireworm, the larvae of click beetle are a subterranean pest feeding on seedlings and tubers. With the withdrawal of many pesticides, farmers are let with very limited options to control subterranean pests. Entomopathogenic fungi such as *Metarhizium brunneum* have a potential as control agent; however, they are slow acting, and their growth is dependent of good edaphic conditions.

Volatiles organic compounds (VOCs) emitted by *M. brunneum* have a potential for IPM through fumigation at high doses or their attractant/repellent properties at lower doses.

During this project, we tried to develop new IPM methods against wireworms (*A. lineatus*) using 1-octen-3-ol and 3-octanone, two VOCs emitted by *M. brunneum*.
In a closed environment, the two VOCs could kill wireworms quickly; however, this effect disappear at low doses in an open environment. Liquid VOCs could slightly repelled wireworms yet not significantly. The volatility of the VOCs could be responsible for the low effect. Thus, VOCs were formulated in slow released granules, which could significantly reduce maize damage for 18 days.

Low doses of VOCs have a high potential to reduce damage in the early season. Yet a better formulation of the granules is needed to extend the activity of the VOCs and increase the duration of the repellent effect.

Trap colours can be improved rationally by modelling insect colour vision: improving coloured targets for tsetse fly control

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Coloured traps are used to control insect pests of many different species. Finding trap colours that attract more insects would improve the efficiency of pest control, but because insects experience colour differently to humans, trap colour development has required trial and error. In contrast, we have shown that insect colour vision can be modelled and used to guide the deliberate engineering of more attractive coloured traps. Tsetse are biting flies that transmit sleeping sickness to humans and nagana to cattle. Tsetse are controlled using insecticide-coated fabric panels called 'targets', and past research had shown that targets that are blue or black to a human eye attracted the most tsetse. Flies possess five different kinds of photoreceptor, so we calculated how these would respond to differently coloured targets and built mechanistic models that explained tsetse catches at those targets based on the sensory information experienced by a fly. Strong responses in a fly's ultraviolet- and green-sensitive photoreceptors decreased target attractiveness, whilst strong responses in blue-sensitive photoreceptors increased target attractiveness. Next, we used colour engineering approaches alongside these mechanistic models to explore the potential attractiveness of different dye combinations in silico, and prototyped a violet fabric that we predicted would have high attractiveness. Finally, we field tested prototype violet fabric targets and found that they caught more tsetse than black and/or blue targets. Our approach can be modified for other pest species and trap designs, allowing trap colour to be improved rationally based upon the way that pest insects experience colour.

IPM and biocontrol by VOCs

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One of the key adaptations of insects is the ability to detect environmental signals, particularly the ability to perceive volatile organic compounds (VOCs) via specialized sensilla for interspecific and intraspecific communication. Indeed, among the various modes of sensory perception, insects predominantly use their olfaction to detect conspecifics, food resources or possible threats. Semiochemicals serve as olfactory cues, eliciting behavioural or physiological responses in the individual perceiving them.

Some VOCs produced by *Zelus renardii* Kolenati, 1856 modify the reduviid behaviour, a stenophagous predator that can prey on the European vectors of *Xylella fastidiosa*. *Zelus* spp. can secrete VOCs from Brindley's glands during interactions with conspecifics and the prey. The blend of secreted VOCs consists of 2-methyl-propanoic acid, 2-methyl-butanoic acid and 3-methyl-1-butanol. Olfactometric tests show that these three VOCs, individually, generate an alarm response in the predator. 3-methyl-1-butanol elicited high repellence, followed by 2-methyl-butanoic and 2-methyl-propanoic acids. The predator modulates the secretion and the release of the mixture depending on stress or the presence of prey. When *Z. renardii* interacts with *Philaenus spumarius* (L., 1758), it reduces the production of alarm pheromones and the possibility of being detected by the prey. In addition, modulation of alarm pheromone production helps the predator to mark its predation territory, pushing away conspecific and thus reducing competition and cannibalism to favour fitness. The ability of *Z. renardii* to tag its predation area may sustain the mass predator release hypothesis to contain the *Xylella*-vector population.

We also tested fungal VOCs secreted by *Beauveria bassiana*, *Metarhizium roberstii* and *Pochonia chlamydosporia* for their ability to repel the *Cosmopolites sordidus* (Germar, 1824) (Black Banana Weevil - BBW), the key-pest of banana groves (*Musa* spp.). Using solid-phase microextraction gas chromatography/mass spectrometry (GC/MS-SPME), we identified 97 different fungal VOCs, identifying seven compounds, namely styrene, benzothiazole, camphor, borneol, 1,3-dimethoxy-benzene, 1-octene-3-ol and 2-cyclohepten-1-one for their abundance or history as insect repellents. 2-cyclohepten-1-one is the best repellent for BBW, followed by 1,3-dimethoxy-benzene. The other VOCs show milder repellence towards BBW. Therefore, all these fungal VOCs can implement BBW biomanagement in the field within a push-pull strategy.

Finally, VOCs show high potential in developing new effective control actions supporting pest and antagonist management. In general, we may use VOCs to manipulate the behaviour of the actors to establish environmentally sustainable integrated management strategies.

Optical sensors for automated detection and identification of insect pests and their natural enemies in oilseed rape crops

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Optical methods of automatically detecting and identifying animals are becoming more common. However, applications to small organisms, such as insects, are relatively scarce despite use cases having the potential for significant developments towards sustainable agriculture. Here we describe the use of two contrasting image-based systems for aerial and ground active insects. (1) We investigated the spatial and temporal dynamics of pollen beetle immigration into oilseed rape fields in Denmark and the UK using multiple methods, including optical sensors. Pollen beetles were found to be aggregated in the field and optical sensors were efficient in detecting their immigration. Detecting insects in flight could lead to the development of targeted spray applications in precision agriculture and faster decision making in integrated pest management. (2) We used stills camera traps to identify and quantify predation of oilseed rape pests by their natural enemies. We revealed unexpected interactions given the available literature. A greater understanding of these relationships and their phenology can help design agricultural landscapes to favour the most important predators in conservation biocontrol. Both types of sensors have potential to lead to the reduction in pesticide use and meeting global targets for reductions in biodiversity loss while maintaining agricultural productivity.

From Field to Cloud – Quantification of chemicals in the Agro-Industries.

Martins Peacock
Zimmer Peacock

From glyphosate and bird flu to mycotoxins, many of the chemicals and pathogens associated with the Agricultural and Horticultural Industries can be detected and quantified using in-field testing technologies. However, the current challenge with chemical testing lies in the collection of samples, which are then sent to centralized laboratories. The resulting delays in obtaining results and the high costs associated with the analysis process tend to diminish the overall utility of testing. In this presentation, we will showcase the implementation of chemical testing at the point of need as a means to ensure food quality.

Improving the forecast of *Grapholita molesta* development in apples

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Forecasting pest phenology is an important tool for IPM as it allows for better planning of control methods. In Catalonia region (NE Spain), there is a public platform with phenology models for the most important pests. However, in Girona province (NE Catalonia), the model used for *Grapholita molesta* Busck (Lepidoptera: Tortricidae) (Croft *et al.* 1980) ceased to properly predict *G. molesta*'s development after it started producing severe damage to apples (*Malus* × *domestica* Borkh). In this study, data from 5 years of captures in monitoring traps located in commercial orchards in Girona and Lleida (SW Catalonia) provinces were evaluated to better understand the population dynamics in both areas. The phenology model historically used in the area for *G. molesta* was used to compare provinces and years. Development studies were conducted for larvae of *G. molesta* fed on apples, both in the lab at 5 constant temperatures, in order to obtain data to build a new phenology model, and also at field conditions to check the results. Two *G. molesta* populations, one from Girona and the other from Lleida provinces, were evaluated in three apple cultivars: Gala, Golden, and Fuji. Finally, the data obtained was used to build a new phenology model using the software DYMEX (Cervantes Agritech Pty Limited). The results showed clear differences in the population dynamics between the two provinces studied. The complete adult flight period was similar in both provinces; however, *G. molesta* generation time was longer in Girona province, and as a consequence, one less generation than expected was detected in this province. The development studies showed no significant differences between the populations of Girona and Lleida provinces. However, significant differences were found between laboratory and field conditions for the same parameters studied. Regarding the development time in different cultivars, in laboratory conditions the shortest was recorded in the Gala cultivar, while in field conditions the shortest was recorded in the Golden cultivar. A new phenology model was built using the data obtained in the previously mentioned studies, which showed better performance for the Girona conditions than the phenology model previously used.

NEW IPM 2023

Unlocking crop protection: Harnessing plant-insect interactions for sustainable pest management

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The increasing global demand for agricultural produce means a food crisis could occur if novel strategies to increase crop yields per area of cultivated land remain undetermined. Insect pests substantially reduce crop yield and quality worldwide, causing economic losses and threating global food security. Growers currently use chemical insecticides to protect crop plants from insect pests, but future use is under scrutiny due to emerging problems of insecticide resistance, off-target effects on beneficial insects, and severe decline in availability of active ingredients. Thus, sustainable alternatives are urgently sought. During their coevolution with insects, plants have evolved an intricate arsenal of defence mechanisms against antagonistic insect herbivores. One of these defences involves the synthesis and emission of volatile organic compounds (VOCs) in response to herbivore attacks. These herbivore-induced volatile organic compounds (HI-VOCs) play exceedingly important roles as infochemicals in plants-insect interactions. While herbivorous insects utilize HI-VOCs to locate suitable host plants as food, the success of natural enemies in locating their host and/or prey also depends on these signals. Biological control is generally accepted alternative to reduce the crop damage caused by insects but is insufficiently effective and is applied only on a relatively small acreage. Increasing the effectiveness of biological control agents, such as predators and parasitoids, not only involves increasing their numbers in agroecosystems, but also enhancing their foraging success. For the latter, it has been proposed that manipulating the volatile emission from crop plants and optimizing crop plants may help improve the foraging efficiency of natural enemies. In my talk, I will focus on the ongoing research efforts to optimize crop plants, improving the foraging success of natural enemies and its implications for biological control.

Keywords: parasitoid attraction; elicitors of plant defence; nectar provision; habitat management.

Hyperspectral Imaging for Visualisation of Early Infections (HIVisEI)

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Hyperspectral imaging is a cutting-edge technique that synergizes spectral (chemical) and spatial (2-dimensional) data, enabling remarkable advancements in identifying and detecting various chemical constituents in produce and tracking chemical changes caused by infections. As food rots or encounters infection, its hyperspectral data, acquired using near-infrared light, reflects its altering chemical composition. The complexity of analysing these hyperspectral images increases due to their high dimensionality, especially when distinguishing between fresh and affected produce with multiple parameters and their relationships.

To address these challenges, machine learning (ML) offers an efficient and automated solution, delivering consistent and reproducible results. Leveraging ML, we can unlock significant potential in assessing food quality based on chemical content, particularly toxic elements, moving beyond conventional "use by date" methods that lead to approximately 1/3rd of edible food going to waste due to inadequate measurements.

The ideal solution involves a non-contact, label-free, and rapid visualisation method capable of precisely detecting chemical contents. To fulfil this vision, we report the integration of near-infrared hyperspectral imaging (NIR-HSI) with sophisticated machine learning methods, presenting a ground-breaking opportunity to achieve our goal of accurate and traceable chemical content quantification.

Attractive Targeted Sugar Baits (ATSBs) as novel tools in mosquito disease vector management

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Attractive Targeted Sugar Baits – sometimes also referred to as Attractive Toxic Sugar Baits – constitute a novel additional tool in the fight against mosquito species that carry important diseases such as malaria, dengue and chikungunya. Mosquitoes require sugar meals as a source of energy in order to mate, oviposit and complete their life cycles. Unlike female mosquitoes, males do not require blood meals to complete their life cycle, but they do require sugar for flight, swarm formation and mating. This they obtain as nectar from flowers, extrafloral nectaries, ripe fruits or from insect produced honeydew. The females of most species also require sugar but can also metabolise ingested blood for energy. ATSBs make use of this need for sugar by attracting mosquitoes to a bait that contains an oral killing agent, attracted to the bait by floral or fruit scents.
This talk describes some of the work that has gone into the development of an ATSB device that has been targeted at *Anopheles* malaria mosquitoes and is currently undergoing epidemiological evaluation in several sub-Saharan countries. The hope is that these devices are capable of reducing malarial infections by reducing the transmission capabilities of mosquito populations by targeted vector reductions.

Integrated larvicide strategy for enhanced mosquito-borne disease control: controlled release novaluron tablet and eco-friendly silicon spreader.

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Mosquito-borne diseases, such as malaria, dengue fever, and Zika virus, impose a significant global health burden. They result in millions of infections and hundreds of thousands of deaths annually, collectively affecting over 2.5 billion people worldwide. Larviciding stands as a crucial component of an integrated mosquito management program, working in conjunction with other strategies to control mosquito populations and reduce the risk of mosquito-borne diseases. In response to the urgent need for effective mosquito control, this study unveils a dual larvicide strategy that combines the Mosqinok 0.8P tablet, powered by novaluron, with the environmentally friendly Silmax as a silicone spreader. By disrupting the mosquito life cycle at its early stages, larviciding helps establish a more sustainable and long-term approach to mosquito control.

Acknowledging the challenges posed by insecticide resistance and the environmental impact of conventional chemicals, this study introduces an innovative approach using Insect Growth Regulators (IGRs). It particularly focuses on the benzoyl urea derivative called Novaluron, which disrupts chitin synthesis and affects the moulting process in insects. This renders it a promising weapon against rapid mosquito breeding. Laboratory and field trials conducted across diverse locations validate the efficacy of novaluron based tablets Mosqinok 0.8P, showcasing mortality rates of over 98% and sustained control over a 12-week period.

The study introduces another innovative solution called Silmax, a silicon-based liquid larvicide, as a sustainable alternative for mosquito control. Unlike traditional chemical insecticides, Silmax is designed to be environmentally friendly and completely non-toxic. Laboratory assessments on pupae and different larval stages demonstrate swift and enduring efficacy, resulting in over 90% mortality within 15 minutes, and increasing to 95-100% within 24-96 hours. Subsequent field trials confirm Silmax's residual efficacy, reducing mosquito larvae presence for up to 60 days. By combining the strengths of both larvicides, an integrated strategy is devised. Mosqinok 0.8P's precision targeting and prolonged effectiveness ensure year-round control, while Silmax's harmless composition and extended efficiency under various conditions promote a sustainable solution. This dual approach mitigates ecological impacts and strengthens the fight against mosquito-borne diseases.

The idea of integrating two different types of larvicides to address different aspects of mosquito control is indeed a strategic approach. By doing so, the study aims to mitigate ecological impacts while enhancing the overall efficacy of mosquito control efforts. This integrated strategy holds potential to contribute to the broader fight against mosquito-borne diseases, all while considering environmental sustainability in regions dealing with conventional insecticide resistance.

Kichawi Kill spore powder, the breakthrough in Striga control

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Witchweed (*Striga hermonthica*) is a parasitic weed that causes high yield losses in maize on more than 200,000 ha in Kenya alone. Striga particularly affects maize, sorghum and millet on approximately 40 million farms across Africa. A new biological herbicide developed in Kenya called Kichawi Kill™ is able to control Striga effectively. The basis for the effect of the product is the ability of the fungus (*Fusarium oxysporum*) used as the effective agent to form certain amino acids. These are methionine, leucine and tyrosine. While the methionine promotes the germination of the striga seeds in the soil, the leucine and the tyrosine interfere with the amino acid biosynthesis of the plant and thus act as a herbicide. The fungal strain used in the product has also been selected for its captan resistance. The strain is deposited in the type culture collection DSMZ in Braunschweig (Germany) under the designation DSM 33471 and patented in Austria. The international patent application (PCT) has been filed and registration in the individual countries is imminent. The German Committee on Biological Agents (ABAS) recently classified the production strain of *F. oxysporum* we use in risk group 1 (no risk to humans).

The Toothpick Company Limited in Kenya has now succeeded in obtaining approval for a seed treatment product containing this strain. The product is a powder containing 3 x 10^7 colony forming units per gram. It has a shelf life of at least one half a year in the refrigerator. Its registration clears the way to effectively treat the contaminated arable land in Kenya with little financial effort and thus help the poor smallholders in particular to earn a living.

Trials at three locations were able to demonstrate the effectiveness of the product impressively. The trials took place in the counties of Busia, Homa Bay and Siaya, which are all located in Western Kenya, on heavily infested fields. In Busia, the maize yield was more than doubled when applying 2 g of spore powder per kg maize seed of the variety Duma 419. In Homa Bay and Siaya, the yield of the Duma 43 variety increased by 81.0 and 87.5%, respectively.

Planting for the short rainy season is currently in full swing. In this first sales season for the newly approved product, around 1000 ha are to be treated. It is planned to increase this number to 45,000 ha by the short rainy season of 2027.

One of the next research tasks is to test the effect of the fungal strain against *Striga acciatica*, another striga species that causes high yield losses, especially in South Asia. The first field trials will begin this year.

How pest resistance to *Bacillus thuringiensis* helps to improve bioinsecticides

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Bacteria *Bacillus thuringiensis* (Bt) is one of the most common sources for biopesticide and gene modified crops used for pest management in the world. Bt produce a wide range of Cry-proteins and other virulence factors against insects, mites, and nematodes. Many cases of insect's resistance to Bt toxins were registered last years. We experimentally selected a *G. mellonella* line over 40 generations for resistance against Bt. The knowledge of the mechanisms of insect resistance give the ways how to enhance the efficiency of biopesticides based on *Bacillus thuringiensis*. As well, the progression of B. thuringiensis subsp. galleriae infection in susceptible (S) and resistant (R) populations of wax moth larvae were investigated to gain further insight into the "arms race" between B. thuringiensis virulence and insect. A sub-population of highly virulent B. thuringiensis can survive the enhanced immune defences of resistant *G. mellonella* by disrupting the midgut microbiome and switching rapidly to a necrotrophic strategy, prior to sporulation in the cadaver. Arm race between virulence factors of Bt and insect resistance is interesting example of coevolution in the field. Sequential passage, and isolation, of Bt through resistant insects for developing highly virulent strains will be discussed. Synergetic effect of Bt bacterial spore and Cry-toxins in Colorado potato beetle (CPB) mortality rate will be presented and clarified in the talk. Symbiont mediated RNA-interference is one of the new approaches in biological pest control. New insight in area of RNAi pest control and Bt polyfunctional activity for potato-pest/diseases interaction will be demonstrated in the presentation. This work was supported by the Russian Science Foundation (grant number 22-16-20031) and Governments of Novosibirsk region (№p-4).

Development and mass production of broad-spectrum fungal pesticides against insect pest and plant pathogen

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Most crops face various pests and diseases during grow season, their combined activities result in major losses to harvest. To control all the major pests of rice, a strategy was developed to screen for broad-spectrum fungal strain with no adverse effects on natural enemies. Serial "strain selection" experiments were conducted based on the host range, conidiation and thermal tolerance of fungal strains, and got a specific *Metarhizium anisopliae* strain (CQMa421) from over 1,000 strains, the strain CQMa421 could control major rice insect pests without affecting natural enemies. Further test showed that CQMa421 can infect 7 order of insects and inhibits most plant pathogens tested. Granule and dispersable oil suspension of CQMa421 were developed and registered as microbial pesticides against insect pest and plant pathogen. A production system for fungal conidia, technical concentrate and formulations has been constructed with annual production capability of 200 tons fungal conidia. The *M. anisopliae* CQMa421 agents have been applied over 1 million hectares in rice, corn, vegetables, oil crops, tea and fruit trees. Long-term, large-scale application results demonstrated *M. anisopliae* CQMa421 agents with or without low dose of chemical pesticides could maintaining agricultural productivity while protecting natural enemies.

Extraction of essential oils for pest control

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Essential oils (EOs) are concentrated hydrophobic liquids containing volatile chemical compounds from plants that retain the natural smell and flavour of their source. Lavender oil, clove oil, and tea tree oil are only few examples of EOs. Each EO has a unique chemical composition, which gives its distinctive properties such as smell, flavour, and effects on other species. More than 300 chemicals can be found in a given EO, with terpenes forming the largest group [1, 2] (examples are shown in Fig. 1). Plant cells synthesise EOs in the plastids and cytoplasm through complex chemical pathways involving methyl-D-erythritol-4-phosphate (MEP), mevalonic acid and malonic acid. One of the main roles of EOs in plants is to protect against pests.

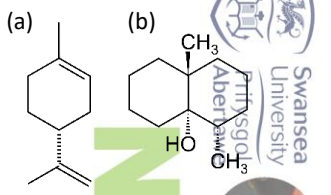

Fig. 1: (a) limonene, a monoterpene (b) geosmin, a sesquiterpenoid

As the negative environmental and health effects of synthetic pesticides multiply in addition to several pests having developed resistance to such chemicals, EOs are being increasingly researched and utilised as a biorational agent in integrated pest management. For example, Rosemary, *Rosmarinus officinalis* (L.), has been used as an effective fumigant agent against various insect pests such as confused flour beetle, red flour beetle, and almond moth [3-5] while thyme and spearmint were found lethal to pest slug *Deroceras reticulatum* [6] and Clove bud oil was lethal to the eggs and juveniles of the quarantine snail pest, *Cornu aspersum* [7]. Although EOs are known for their potent activity as insecticides and fungicides, research related to their use as molluscicides is limited [8]. To date, only very few EOs have been identified for slug and snail control at non-phytotoxic concentrations.

Extraction of the EO and its formulation into a suitable product are amongst the challenges that require significant effort before the EO is deployed as a biopesticide. This paper will review the different techniques used to extract EOs giving a particular focus on hydrodistillation and microwave assisted EO extraction. The latter technique is currently used in our labs to develop an EO for pest control. In addition, this paper will discuss key techniques used for EO formulation and demonstrate the stability of emulsions developed in our labs. It can be concluded that plant-derived essential oils (EOs) are green pesticides, which are effective, sustainable, biodegradable, and generally harmless to the environment when compared to synthetic pesticides. Their use to reduce synthetic pesticides is also essential to protect the environment and our water supplies.

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Single-cell polymer coating improves desiccation tolerance of *Metarhizium brunneum* blastospores

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Equipping cells with artificial shells or coats have been explored throughout the last decade, with goals such as immuno-masking, in-vivo tracing, and imparting tolerances toward various biotic and abiotic stressors. One stressor, however, drying, has curiously been overlooked.

In an industrial setting, the drying of cells becomes relevant when a satisfactory product shelf life must be achieved at low costs. The drying of entomopathogenic organisms for biocontrol in agricultural settings is a prime example of this. Here, the thin-walled blastospores of the entomopathogenic fungus *Metarhizium brunneum* are a great model organism to test whether thin cell surface coats may increase desiccation tolerance.

A commonly employed technique for film or coat fabrication is called layer-by-layer fabrication: Via electrostatic interaction, a charged polymer adheres to an oppositely charged surface creating a dense polymer layer. This in turn, reverses the original surface charge so that another dense polymer layer may adhere to the initial layer. By repetition of these steps, surface coats of varying thickness can be created. By utilizing a the natural surface charge, cells may be coated on a single-cell level with this method.

We will highlight the ability of this exciting technique to increase the desiccation tolerance and drying survival of single *Metarhizium brunneum* blastospores. Furthermore, we will showcase the coats tunability in dependence of parameters such as number of polymer layers and polymer chain length. Lastly some pitfalls of single-cell desiccation analytics will be discussed.

NEW IPM 2023

Incidence and distribution of termite nests on grasslands: a prerequisite for their management and control under field conditions

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In order to evaluate the incidence and distribution of termite populations on the production of native grassland (*Paspalum notatum* L.), cattle farms and their surroundings were sampled in Itacurubi del Rosario - department of San Pedro - Paraguay. The termite mounds were located using the Garmin Map 76 CSx GPS device and drones equipped with cameras to capture aerial photographs. Incidence and distribution maps of termite mounds were made for the surface of one and seven hectares. From the data generated, a map with the distribution of active termite mounds was prepared using the QGIS software version 3.18. The formation of termite mounds represented an average area of 12 m² and an intensity of 13.5% per hectare, distributed in an average of 96.2 termite mounds per hectare, totaling some 673.4 termite mounds within the study area for a total area of 7 ha. The Termitidae family was represented by the following species: (*Cornitermes cumulans*, *Nasutitermes nigriceps* and *Termes* sp.), widely distributed in the study area. The number of termite mounds found probably affects the useful productive area of the pasture, as well as the availability of pastures for animal feeding at different times of the year.

Keywords: *Cornitermes cumulans*, *Nasutitermes nigriceps*, grassland, termitidae, *Termes* sp, termite mound.

Eco-friendly strategy to control toxigenic Aspergillus spp. on nuts based on early detection by Loop-mediated isothermal amplification (LAMP) and alternative pre- and post-harvest treatments.

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Although Aspergillus contaminations and the mycotoxin production that can result are typically perceived as mainly post-harvest issues, they are complex phenomena that originate in the field and relate to several factors. An effective control strategy must be implemented as early as possible to prevent and, if necessary, minimize contamination throughout the production cycle. An effective control strategy requires, first and foremost, monitoring of contamination by means of continuous mass screening using a cost-effective, easy and accurate detection method. Loop-mediated isothermal amplification (LAMP) seems to check all these boxes. During our study, we successfully developed three user-friendly LAMP kits, two of which are species-specific in order to detect A. flavus, and A. parasiticus, while the third is a generic kit for detection of any aflatoxigenic Aspergillus sp. The kits were validated in testing involving pistachios and almonds and showed high sensitivity and specificity to their targets. Second, accurate detection must be followed by an effective control safe for consumers and the environment. We tested the effectiveness of bio-control agents including Bacillus spp. And Trichoderma spp. as pre-harvest treatments to reduce A. flavus contamination on pistachio and almond-based substrates. The primary in vitro tests showed promising results with a high growth inhibition by competition. Furthermore, the efficacy of ozone, a cost-effective and eco-friendly food-processing technology, was evaluated as a post-harvest treatment for nuts; it showed a significant reduction of Aspergillus spores on both pistachios and almonds without provoking deterioration in their nutritional value even after prolonged storage. The early monitoring of toxigenic Aspergillus contamination on nuts by LAMP and prevention by means of alternative pre- and post-harvest treatments can significantly diminish and control this health threat, accordingly problematic for the marketing of many food commodities.

Current status of *halyomorpha halys* (stål, 1855) (hemiptera: pentatomidae) in Türkiye and its associated biocontrol using *Trissolcus japonicus* (hymenoptera: scelionidae)

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Halyomorpha halys (Stål, 1855) (Hemiptera: Pentatomidae), the brown marmorated stink bug (BMSB), is an alien invasive pest that is native to Asia. Since the insect was first detected in 1996 in Allentown, USA, it has spread to many countries; Switzerland in 2007, UK and Canada in 2010, Georgia in 2015, and Türkiye in 2017. The pest is a polyphagous insect that causes severe damage due to its wide host range, high reproductive rate, long-distance flight, and adaptation abilities. *Halyomorpha halys* adults and nymphs damage host plants by piercing their surface and injecting digestive enzymes or sucking fluids and it causes damages such as necrosis, and deformation on crops and ends up with quality and/or yield loss. BMSB outbreaks have resulted in economic losses in fruit and vegetable production in many countries such as Italy, China, Japan, and the USA. Although different control methods are adopted such as chemicals, entomopathogens, and pheromone traps by each country, classical biological control seems one of the most important components in long-term management. BMSB was reported in 2017 in Türkiye for the first time and since 2019, survey studies have been conducted by the Black Sea Agricultural Research Institute to detect the population rate and dispersal. Within the scope of the classical biological control project of *Halyomorpha halys* in Türkiye, egg parasitoid *Trissolcus japonicus* was imported from CREA in Italy in 2022 for mass production and the biological control was started by releasing the wasps in 3 sites in 2023.

Key words: *Hayomorpha halys*, Classical Biological Control, *Trissolcus japonicus*

Overview of Defra's IPM R&D

H ALPREN

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With IPM at the heart of our approach, we want to see a renewed and more sustainable agricultural sector, producing food for consumption at home and abroad, where farms can be profitable and economically sustainable. We want to support innovation and R&D to develop new and effective ways for managing pest and disease. To achieve this, priorities include:

1. Building an understanding of the context – we commissioned a review into recent agronomic trends and their benefits and risks. We have also funded additions to the crop pest and disease survey.
2. Targeting R&D where it is needed – we are funding work to better understand the cabbage stem flea beetle (CSFB) lifecycle and IPM strategies that might help to control it. We also fund the Genetic Improvement Networks which aid the development of disease resistant varieties of key crops.
3. Supporting implementation of alternatives – we have funded the project 'IPM Theory of Change' aimed at understanding the barriers and support that farmers use when engaging with IPM, as well as developing an IPM network to help gather data on IPM metrics, yield and profit to assess economic viability of different IPM options.
4. Measuring impact – Defra has funded the development of the pesticide load indicator aimed at assessing load on the environment from different pesticides. We also fund research into pesticides found in honey to assess levels of exposure.

NEW IPM 2023

Drone delivery of beneficial insects and mites for pest control in open field crops: Experiences from the USA

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In the USA, biological control agents (BCAs) are increasingly being used and investigated to control arthropod pests in open field crops. While BCAs including beneficial insects and mites are still mostly used in high value protected crops (greenhouse/nursery), various macroeconomic factors are changing this balance. Thus, we anticipate the trend towards using these BCAs in outdoor field crops will continue.

One aspect favouring the adoption of beneficial mites and insects in field crops is the development of specially adapted drones for BCA application. This technology allows farmers to deploy BCAs quickly to large areas, that otherwise cannot easily be treated by ground equipment or manual labour.

Over the past 3 years, we have seen increasing number of crops treated with BCAs by drones, including strawberries, leafy greens, tree fruits, nuts and hops. However, achieving success is not always easy, and there are still significant barriers for more wide-scale adoption.

In this presentation, I describe my experiences using aerially applied beneficial insects and mites for pest control in the USA. I share perspectives from a beneficial insect industry, drone specialist (pilot), as well as from interactions with growers seeking practical solutions for their pest problems.

IPM: Addressing the challenges in the UK context

Aoife Dillon

Fera Science Limited

Under the UK's 25 Year Environment Plan, published in 2018, the UK government committed to "Putting Integrated Pest Management (IPM) at the heart of a holistic approach, by developing and implementing policies that encourage and support sustainable crop protection with the minimum use of pesticides". One mechanism designed to support this plan is Defra's Sustainable Farming Incentive (SFI) Standard on IPM, published in 2023, which included payment for specific actions related to IPM planning, improving habitat for natural enemies and decreased pesticide use. In this talk we will discuss two recent surveys which looked at how IPM, and biopesticide use, are currently viewed and what changes could be made to drive better adoption. The first survey was commissioned by Fera and included feedback from biopesticide manufacturers, advisors, and end users, while the second survey focused on farmers as was generated under the Test and Trials programme run by the NFU, ADAS and SRUC. Results of both surveys will be presented, including progress on delivering support tools and how changes in payments under the new SFI programme are expected to affect uptake.

Navigating regulatory procedures for weed biological control using non-native agents in the UK

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In the European region, the UK has been at the forefront of implementing the strategy of classical biological control of non-native invasive plant species, exploiting co-evolved natural enemies from their respective geographic centre of origin. In the 1990s, research commenced on the first target, the invasive weed Japanese knotweed (*Fallopia japonica*) for which two agents were evaluated - the psyllid *Aphalara itadori* and the fungal leaf-spot pathogen *Mycosphaerella polygoni-cuspidati*. The case of the psyllid effectively established the regulatory pathway for considering the release of a classical weed biocontrol agent in an EU country, which was authorised in the UK in 2010. The leaf-spot pathogen, however, had to follow a different regulatory route, having been proposed as a potential mycoherbicide based on a non-native agent; the pathogen received permission for release from quarantine for use in experimental field trials in 2019. Classical releases have also been made against the invasive species Himalayan balsam (*Impatiens glandulifera*) using the rust pathogen *Puccinia komarovii* var. *glanduliferae* (2014), *Crassula helmsii*(Australian swamp stonecrop) using the eriophyid mite *Aculus crassulae* (2018) and *Hydrocotyle ranunculoides* (floating pennywort) using the weevil *Listronotus elongatus* (2021).

This talk will detail the Pest Risk Assessments and regulatory processes that the different agents had to go through in the UK and how these developed over time, as well as the challenges encountered along the way. With the agents for Japanese knotweed currently being taken up by the Netherlands and those for the other named weeds under consideration, the paper will also show how the respective PRAs for the UK form the basis for the regulatory process in other European states.

Different thrips species and damage to nectarines under Integrated Pest Management and Organic Management in Lleida and Girona Provinces (Catalonia, Spain)

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Thrips are one of the main pests in nectarines in the Ebro Valley area (NE of Spain). When the attack occurs during blooming the damage by thrips is russeting or even deformation, but, in this production area, the most common damage to nectarines occurs during ripening, at the final moment of fruit phenology, causing silvering on the fruit surface. Thrips can have severe economic consequences when the damage is widespread. The western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) (WFT) is the main species related to silvering damage in nectarines, nevertheless, in recent years, in the intensive production area of Lleida (SW of Catalonia), very significant levels of the species *Thrips fuscipennis* (Haliday) (Thysanoptera: Thripidae) have been detected.

To determine which is the dominant species and the main responsible for the silverling damage in the nectarines in the area, thrips were surveyed for two years (2020 and 2021) in the period corresponding to the BBCH scale of 85 (colouring of fruits advanced) in 6 orchards, three ecological management farms (EM) and three integrated management farms (IM). The species composition of thrips in Girona province, a non-intensive production area, was also determined, surveying four IM and one EM orchards every year.

Four blocks of 10 trees were sampled in each orchard, collecting five leaves, beating one small branch and 2 fruits from each tree. Leaves were introduced in Berlese-Tullgren funnels (Burkard Scientific, UK), and the level of damage to the fruit was evaluated, the number of individuals counted and the adults on it collected for later identification.

In the intensive productive area, the predominant thrip species in the canopy of the tree was *T. fuscipennis*, both years and in both kind of management orchards. Both years, EM orchards obtained much less silverling affectation than IM orchards with very low proportion of non-commercial fruits (more than 5 % of silvering on the fruit surface), less than 4 % of fruits in EM orchards versus more than 47 % of non-commercial fruits in IM orchards. In Girona, the non-intensive productive area, the main thrip species was *F. occidentalis.* Both years, the number of thrips collected in the canopy of the trees and identified was very low (55 and 11 in 2020 and 2021, respectively). In those orchards there were no differences between management systems, and thrips were not a problem.

Identification of entomo-pathogenic fungi of *Atta sexdens rubropilosa* in a silvopastoral system

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Yasú leaf cutter ants (*Atta sexdens rubropilosa*) are social insects made up of a queen, soldiers, workers, gardeners and drones, forming a well-organized nest that is difficult to manage and/or control. In Paraguay, in the last decade, it has become an important invasive pest for both forestry and agricultural crops. The objective of this research was to identify entomopathogenic fungi (HE) in the area of influence of nests, located in commercial silvopastoral plots of *Urochloa brizantha* MG-5 and Eucalyptus sp. The methodology to isolate HE was the use of insect traps or baits based on queen ants, collected and installed during the nuptial flight season of the ant nests. Soil samples from the silvopastoral plots and grass roots (*U. brizantha*) were used. They were also isolated from collected dead insects. The data generated on the incidence of fungal insects were subjected to analysis of variance and the means were subjected to Tukey's test. The comparison of the populations of leaf-cutter ants was carried out using the non-parametric Kruskal-Wallis test for independent samples, whose results showed that there were no significant differences between nests for the fungal ants variable (H=2.463; p>0 .05) and for the variable, deceased from other causes (H=3.806; p>0.05). The entomopathogenic fungi identified were *Beauveria bassiana* and *Metarhizium* sp. isolated from mycorrhizal cutter ants obtained from the area of influence of nests in a silvopastoral system.

Keywords: *Beauveria*, Biocontrol, *Insect traps*, *Metarhizium*, Yasú.

Combined use of imidacloprid to subletal doses and entomo-pathogenic fungi as an alternative for the control of active nests/termite tacurúes

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Termites are considered one of the main pests for pastures and for their control in this work the use of sublethal doses of insecticides combined with entomopathogenic fungi (FE) is proposed. The experiments were conducted in open field conditions in situ, their objectives were to evaluate the effect of the combined use of five FE strains of the genera *Beauveria bassiana*, *Metarhizium anisopliae* and *M. brunneum*) and Imidacloprid at sublethal doses (I db) (Ma +I db; Mb ARSEF 4556 + I db; Bbs + I db) on active populations of termite mounds/tacuru with their respective controls. Two tests have been applied, one on the efficiency of the insecticide (high, medium and low dose) and the combined treatments (FE and I db). Among the results, three species of termites (*Cornitermes cumulans*, *Nasutitermes nigriceps* and *Termes* sp.) have been identified and the insecticide efficiency (I) varies between 80 to 100 % for low to high doses compared to controls (medium control). and absolute) that exhibited an inactivity rate of 0%, respectively, at 60 days after application (daa). While the combined application (FE + I) presented an efficiency of 60% to 100% control efficiency for the combined treatments (Ma + I db) and (Mb 4556 + I db) at 60 daa, respectively. In addition, 100% control of tacurús to the fungal strains used at 90 daa has been demonstrated.

Key words: Termite, Tacurú, Grassland, Fungi

3-octanone from *Metarhizium brunneum* attracts and kills the Brown Garden Snail

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The brown garden snail (*Cornu aspersum*) formerly known as *Helix aspersa* is one of the highly destructive pests of economically important crops. It damages several ornamental and arable crops such as cereals, potatoes, lettuce when feeding on these agricultural crops. Chemical molluscicides such as metaldehyde are major control agents. However, development of alternative methods which do not pose a risk for environment and animal/human health are of paramount importance. This study aimed to detect the response of *C. aspersum* to 3-octanone produced by the insect pathogenic fungus *Metarhizium brunneum*. Both laboratory and field choice assays were performed to determine the behavioral response of the brown garden snail to 1, 10, 100 and 1000 ppm of 3-octanone. Laboratory results showed repellency activity at 1000 ppm while 1, 10 and 100 ppm were attractant for the snails. Results of the field study showed attraction for all concentrations with the most attractive concentration being 100 ppm. Furthermore, 3-octanone was toxic to the snails even at 1 ppm. However, 100 ppm was the most attractive and lethal dose to the snails. This study demonstrated that 3-octanone is an excellent candidate for the potential use as an attractant and molluscicide in lure and kill strategies for the control of brown garden snail.

Key words: Brown Garden snail, 3-octanone, Lure and kill, Molluscicide

Bioprospecting the environmental microbiome of Crete towards the development of novel biopesticides

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Increased emergence and spread of resistance against current insecticides amongst a wide range of both disease vector and agricultural pest insects has rendered ineffective many traditional forms of chemical control. This trend poses serious threats to public health, food security and economies relying on agriculture. Furthermore, the negative impact of many insecticides on human and animal health, and the environment, has resulted in new regulations favouring the development of 'green' biopesticides within the European Union. Prospective biopesticides include entomopathogenic bacteria and fungi as living organisms, alongside their inactivated forms and derived secondary metabolites. We have extensively surveyed a range of diverse Cretan natural habitats to establish a library of over 1500 microorganism isolates. Bioassays against larval stages of the mosquito species *Culex pipiens molestus* and *Aedes albopictus*, as well as the model agricultural pest *Tenebrio molitor*, has yielded a collection of microbes with entomopathogenic activities that appear to rely on different modes of action and to meet basic criteria for biopesticide development. Our ongoing studies are focusing on the spectrum of activity, mode of action and other characteristics of promising candidates to evaluate their suitability for biopesticide development and commercialization and use within integrated vector and pest management programmes.

Keywords: biodiversity, biopesticides, microorganisms, mosquito

Optimizing the Application Timing and Dosage of *Metarhizium brunneum* as a Biological Control Agent *of Aedes aegypti* Larvae

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Aedes aegypti is the vector of a wide range of diseases that affects 50-100 million people worldwide. Insect pathogenic fungi such *as Metarhizium brunneum* have been shown effective in killing *Aedes* mosquito larvae, and the mortality is dose dependent. However, it is essential to understand how larval population dynamics will affect the development of effective control strategies.
This study investigated the susceptibility of *Aedes* larvae to conidial treatment of *Metarhizium* whilst larval population dynamics are changed and adjusted to simulate natural fluctuations exhibited in typical breeding grounds.

In the constant larval immigration assay, the peak mortality was on the Fourth day, prior to a significant reduction in control efficacy linked to a decline in conidial availability within the water column. This suggests that in the field *Metarhizium should be applied against Aedes larvae every 4 days at concentration* 10^7 conidia ml^{-1} to achieve affective control.

Key Performance Indicators (KPIs) proposed by Certis Belchim, to contribute to the improvement of farm sustainability that resulted from new Integrated Pest Management (IPM) programmes

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The European Green Deal and the Farm To Fork strategy establish a number of goals focusing sustainable food production to be reached in 2030 for EU countries. Among those there is the target to reduce by 50% the use of chemical plant protection products. This brings new crop protection challenges for EU farmers, increasing the need for innovative and sustainable solutions.

Certis Belchim B.V. has, over many years, developed and registered at EU and country level a range of biorational plant protection products now actively included in IPM programs across EU countries.

The company started some years ago in Spain the project 'Growing For The Future' (G4TF) to provide complete crop program solutions and technical support to growers, enabling them to respond to the demands of the food chain and consumers for food safety and sustainability. The crop programs proposed to the growers were IPM-based and improved with biocontrol. An additional initiative has been the technical training, within the 'Growing Academy' project, of advisors, technicians, and growers, on the correct use of biorational products, involving also contributions and expertise from local Accademia.

In our IPM crop programs the focus was on the sustainability, seen this from the farmer perspective, looking at technical, environmental, and economic horizons together. In order to give evidence and trust to the farmers in this new tool for their decision-making, the evaluation of the sustainability at farm level is done in collaboration with the farmer and independent research organizations. The final evaluation is done with the following metrics: (i) effectivity in controlling target pests evaluated at the end of the season; (ii) reduction of the number of active ingredients from synthetic chemistry ; (iii) pesticide residues detection and their level compared to MRL; (iv) environmental impact evaluation via EIQ value (Cornell University), measuring beside the environmental impact also that on the workers and consumers; and (v) profitability: at grower level comparing farmer costs and benefits, measuring yields and price.

After the success of Growing For The Future "G4TF" project in Spain, this is now transferred to other European countries for their key crops.

NEW IPM 2023

The use of remote sensing for the assessment of forest growth

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Pest and diseases both impact and are impacted by forest growth and management. This presentation discusses the potential of remote sensing from different platforms and different sensors to monitor forest growth and for pest risk assessment.

Drones offer the opportunity for rapid deployment to determine the outer surface of a tree canopy, often requiring combination with complementary datasets to obtain a canopy height model. Repeat airborne lidar surveys now provide a valuable opportunity for monitoring forest growth, though repeat datasets are not without their challenges. Finally, optical satellite remote sensing provides observations over large areas which can be used to detect pest outbreaks and also for risk assessment to inform management decisions.

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