3rd International Congress of Biological Control

Scientific Programme

San José, Costa Rica 24-27 June 2024

CABI · IOBC OILB · Universidad de Costa Rica · IICA · Ministerio de Agricultura y Ganadería · Gobierno de Costa Rica

JOIN THE IOBC!

If you are interested in making the world a better place by reducing the amount of pesticide sprayed, consider joining the International Organization for Biological Control. This not-for-profit organization brings together the community of biological control scientists from all over the world to discuss, debate and study nature-based solutions for crop pests and invasive alien species. The IOBC organizes meetings and provides support for scientists to attend these meetings. It further provides insight into new developments into the discipline.

Membership

Membership of the organization is open to all individuals and all organizations, public or private, that desire to promote the objectives of the organization.

There are four categories of membership:

Individual Members
Individual membership is open to all individuals engaged or interested in biological control.

Institutional Members
Institutional membership is open to any institution, including government departments, academies of science, universities, institutes and societies, participating in biological control activities.

Supporting Members
Supporting membership is open to any person or institution interested in promoting the objectives of the organisation.

Honorary Members
Honorary membership may be conferred by Council upon anyone who has made outstanding contributions to biological control.

Membership Application
Application for individual membership can be made to the Treasurer of the organization (treasurer@iobc-global.org). The applicant can request affiliation to any Regional Section. For other categories of membership, please contact the Secretary General (secretary-general@iobc-global.org). The Council decides on admission and will determine the appropriate category of membership, if any, of each applicant.

Acknowledgements

We are very grateful to the following individuals for their help in organizing the 3rd International Congress of Biological Control, which is the flagship event of the International Organization of Biological Control (IOBC). The congress is held every three to four years and the 2024 congress is being co-organized by IOBC and CAB International (CABI) and locally supported in Costa Rica by the Inter-American Institute for Cooperation on Agriculture (IICA), the Ministry of Agriculture and Livestock of Costa Rica (MA&L), and the University of Costa Rica (UCR).

Overall Organization & Local Organizing Support:

Ulli Kuhlmann (CABI, Switzerland), Martin Hill (President IOBC Global, Rhodes University, South Africa), George Heimpel (Past President IOBC Global, University of Minnesota, USA), Yelitza Colmenarez (CABI c/o UNESP, Brazil), Harold Gamboa (IICA, Costa Rica), Karla Maria Mena (MA&L), Maria del Milagro Granados (UCR) and Heike Kuhlmann (KCS Convention Service, Switzerland).

Scientific Session & Panel Organizing Members:

Session 1: Julie Coetzee (Rhodes University, South Africa), Alejandro Sosa (Fundación para el Estudio de Especies Invasivas- FUEDEI, Argentina) & Melissa Smith (USDA ARS Invasive Plant Research Lab, Florida, USA); Session 2: Kris Wyckhuys (Chrysalis Consulting, Vietnam) & Lessando Gontijo (University of São Paulo – Esalq, Brazil); Session 3: Yelitza Colmenarez (CABI c/o UNESP, Brazil) & Lorena Barra Bucarei (Instituto de Investigaciones Agropecuarias, Chile); Session 4: Martin Hill (Rhodes University, South Africa) & Ulli Kuhlmann (CABI, Switzerland); Session 5: Laura Varone (Fundación para el Estudio de Especies Invasivas, Argentina) & Maria Belén Aguirre (Fundación para el Estudio de Especies Invasivas- FUEDEI, Argentina); Session 6: Tara Gariepy (Agriculture and Agri-Food Canada, Ontario, Canada) & Jason Schmidt (University of Georgia, Georgia, USA); Session 7: Gonzalo Avila (The New Zealand Institute for Plant and Food Research Limited, New Zealand) & Jana Collatz (Agroscope, Switzerland); Session 8: Matthew Tinsley (Stirling University, United Kingdom) & Yelitza C. Colmenarez (CABI c/o UNESP, Brazil); Session 9: Michelle Fountain (NIAB, United Kingdom) & Liam Harvey (Biobest Group, United Kingdom); Session 10: Tania Zaviezo (Universidad Catolica de Chile, Chile), Simone Mundstock Jahnke (Universidade Federal do Rio Grande do Sul, Brazil) & Yelitza Colmenarez (CABI c/o UNESP, Brazil); Session 11: Lynn M. LeBeck (Association of Natural Biocontrol Producers, California, USA); Session 12: Alejandro Tena (IVIA, Spain), Iain Paterson (Rhodes University, South Africa), Greg Wheeler (USDA/ARS Invasive Plant Research, Florida, USA) & Guy Sutton (Rhodes University, South Africa); Session 13: Joan van Baaren (University Rennes, France) & Colmenarez Yelitza (CABI c/o UNESP, Brazil); Session 14: Kim Weaver (Rhodes University, South Africa), Grant Martin (Rhodes University, South Africa), Lorena Barra Bucarei (Instituto de Investigaciones Agropecuarias, Chile) & Malvika Chaudhary (CABI, India); Session 15: Kelley Leung (University of Groningen, The Netherlands) & Leo W. Beukeboom (University of Groningen, The Netherlands); Session 16: Feng Zhang (CABI, China) & Oliver Bach (Sustainable Agricultural Network, Costa Rica); Session 17: Modesto Olanya (USDA-ARS, ERRC, Pennsylvania, USA) & Adelumula Oladeinde (US National Poultry Research Center, Georgia, USA); Session 18: Ivan Rwomushana (CABI, Kenya) & Frank Chidawanyika (ICEPE, Kenya); Session 19: Marc Bardin (INRAE, France); Session 20: Lorena Barra Bucarei (Instituto de

Investigaciones Agropecuarias, Chile), Yelitza Colmenarez (CABI c/o UNESP, Brazil), Daohong Jiang (Institute of Plant Protection, Chinese Academy of Agricultural Sciences, China) & Jiatao Xie (Huazhong Agricultural University, China); Session 21: George Heimpel (University of Minnesota, USA); Session 22: Justice Tambo (CABI, Switzerland) & Beatrice Muriithi (ICEPE, Kenya); Session 23: Matthew Tinsley (Stirling University, United Kingdom) & Yelitza Colmenarez (CABI c/o UNESP, Brazil); Plenary Session 1: Martin Hill (Rhodes University, South Africa); Plenary Session 2 & 3: Ulli Kuhlmann (CABI, Switzerland), Plenary Session 4: George Heimpel (University of Minnesota, USA) and Plenary Session 5: Andy Sheppard (CSIRO, Australia), Martin Hill (Rhodes University, South Africa) & Raghu Sathyamurthy (CSIRO, Australia)

Scientific Programme & Abstract Booklet & Congress Design:

Gitta Grosskopf-Lachat (CABI, Switzerland), Sarah Hilliar and Tom Swindley (CABI, United Kingdom)

Sponsorships:

We acknowledge the financial support of IOBC and CABI to support the organization and implementation of ICBC3 in Costa Rica. Furthermore, IOBC and CABI provided additional and restricted funds to support travel grants for young scientists and to significantly reduce the registration fees for scientists from the LATAM region. We would like also to acknowledge the in-kind contributions from IICA for supporting the entire visa process and organizing technical field trips; the Ministry of Agriculture and Livestock of Costa Rica for making key personnel available and for supporting the organization of technical field trips; and the University of Costa Rica for ensuring the availability of technical assistants to support the local implementation of ICBC3.

IOBC is affiliated with the International Council of Scientific Unions (ICSU) as the Section of Biological Control of the International Union of Biological Sciences (IUBS).

The International organisation for Biological Control (IOBC) was established in 1955 as a global organisation affiliated to the International Council of Scientific Unions (ICSU). IOBC promotes environmentally safe methods of pest and disease control. It is a voluntary organisation of biological-control workers.

Membership in IOBC gives individuals and organisations the opportunity to participate in biological control activities beyond their specific jobs and workplaces, to step outside their bureaucracies, and to contribute to the promotion of biological control worldwide.

- IOBC promotes the development of biological control and its application in integrated pest management programs, and international cooperation to these ends.
- IOBC collects, evaluates and disseminates information about biological control, and promotes national and international action concerning research, training of personnel, coordination of large-scale application and public awareness of the economic and social importance of biological control.
- IOBC arranges conferences, meetings and symposia, and takes other action to implement the general objectives of the organisation.
- As an independent professional organisation, IOBC can be an effective advocate for biological control, and can influence policy makers and Governments.
- IOBC assists in the communication among biological-control workers, through dissemination of the IOBC Newsletter.
- IOBC publishes a journal for basic and applied research on biological control of invertebrate, vertebrate and weed pests, and plant diseases. This journal is BioControl, published by Springer. Information about BioControl can be found at **https://www.springer.com/life+sci/entomology/journal/10526**

CABI is an international, intergovernmental, not-for-profit organization that improves people's lives by providing information and applying scientific expertise to solve problems in agriculture and the environment. The majority of CABI's development work is thus in the application of scientific knowledge, rather than in pure research programmes. However, CABI's implementation projects are supported by a core programme of research into invertebrate pests, plant diseases and weeds, and the use of climate-smart pest management methods including nature-based plant protection inputs which can control them. The principal beneficiaries of CABI's scientific research programmes are farmers (women, men and youth) gaining access to sufficient safe and nutritious food, as well as improved livelihoods from better market access, through sustainable, climate resilient agriculture in healthy ecosystems.

Climate change and gender and social inclusion are two overarching drivers for CABI's current Science Strategy, which is considered in all CABI's research. CABI's Science Strategy has identified the following Priority Research Areas:

- **Priority Research Area 1**: The impact of pests. Quantifying the impact of pests (invertebrate pests, plant diseases and weeds) on livelihoods, yield, biodiversity, and ecosystem functioning as affected by climate change
- **Priority Research Area 2**: Management of invasive alien species. Developing, validating and evaluating climate-smart ecosystem management approaches for invasive species to tackle emerging pests that threaten crops and livelihoods on the one hand and protect and restore biodiversity on the other
- **Priority Research Area 3**: Improved and safer food systems. Evaluating the advocacy of safe and effective biological control-based plant protection systems by advisory services, their use by farmers and its impact on production, quality and safety in plant health systems
- **Priority Research Area 4**: Advisory services and communications tools. Designing, validating and evaluating new extension approaches and communication tools to meet female and male farmers' needs

Complementing CABI's Priority Research Areas, we anticipate several cross-cutting research approaches which will underpin and add value to the Priority Research Areas: modelling and data science, molecular biology and microbiology, and monitoring and evaluation.

The Inter-American Institute for Cooperation on Agriculture (IICA) is the specialized agency for agriculture of the Inter-American System that supports the efforts of Member States to achieve agricultural development and rural well-being.

The Institute provides cooperation services through close and permanent work with its 34 Member States, addressing their needs in a timely manner. Without a doubt, IICA's most valuable asset is the close relationship it maintains with the beneficiaries of its work. IICA has broad experience in areas such as technology and innovation for agriculture, agricultural health, food safety and quality, international agricultural trade, family farming, rural development, natural resource management and the bioeconomy.The four strategic objectives organize and systematize the countries' development strategies and, consequently, IICA's technical cooperation actions.

Our roadmap is based on seven hemispheric programs, which lend uniqueness to IICA's vision; channel the Institute's programmatic actions toward the identification of cooperation actions through the design and implementation of projects; and provide technical advice and assistance to governments and other social and economic stakeholders involved in agricultural and rural life in the Americas. Within the seven hemispheric programs there is one focussing on Innovation & Bioeconomy.

Within the strategies of the bioeconomy, the development and use of bioinputs is a key topic on which the institute has focused significant efforts to promote these biological-based tools as nature-based solutions that can significantly contribute to the sustainability of agri-food systems, reduce the carbon footprint, minimize the environmental impacts generated by agricultural activities, help conserve biodiversity and local biological resources, and generate more job opportunities in rural areas of LAC. For this purpose, the Hemispheric Bioinputs Platform was created and launched, an international initiative that promotes multilateral cooperation and the exchange of experiences so that countries can strengthen the development and promotion of bioinputs in the region from scientific and technological, regulatory, and capacity-building perspectives.

MINISTERIO DE AGRICULTURA Y GANADERÍA | GOBIERNO DE COSTA RICA

The Ministry of Agriculture and Livestock of Costa Rica is the entity responsible for defining and guiding public policy for the development of the Costa Rican agricultural sector. In its management, it seeks to promote the dignity of rural families of small and medium-sized producers, promoting the development of their technical and management capabilities in productive systems and agricultural organizations, to improve agricultural activities' competitiveness, equity, social, economic, and environmental sustainability.

Through its Agricultural Extension services, distributed all over the country, it provides quality, timely, and effective services, focused on supporting the satisfaction of food and nutritional security needs of rural families and improving their quality of life.

The Agricultural and Livestock Sector is of great economic and social relevance; this is reflected in its share of the Gross Domestic Product (GDP), exports (currency source), as well as in its contribution to employment.

Within the framework of policies issued by the Ministry of Agriculture and the Costa Rican Agricultural Sector are:

1. The Public Policy for the Costa Rican Agricultural Sector 2023-2032, which aims to enhance economic, social, and environmental sustainability through the implementation of tools and mechanisms that contribute to the development and well-being of the population linked to the Costa Rican Agricultural Sector. It also establishes a close relationship with the Sustainable Development Goals, contributing to their fulfillment.
2. The State Policy for Territorial Rural Development (PEDRT) 2015-2030, whose general objective is to promote the inclusive development of rural territories, recognizing and respecting their own characteristics and cultural identity of their population, through a public-private articulation system, which reduces economic, social, cultural, environmental, and political-institutional inequalities and inequities, through capacity development and opportunities for their inhabitants.
3. The National Seed Policy 2017-2030 has the objective of developing the Costa Rican seed sector with an articulating approach to the interests and resources of its members, to improve the productive efficiency of the Agricultural Sector, in response to the challenges posed by food and nutritional security, conservation of biodiversity, climate change, globalization of markets, and quality assurance.

The University of Costa Rica (UCR) is a high education institution recognised throughout Latin America and a standard bearer of humanistic education, where generations of socially committed professionals have been trained. Since 12 March 2001 it has been designated as a meritorious Institution of Costa Rican Education and Culture.

According to the QS World University Rankings 2024, the UCR is ratified as the best university in Central America and one of the 19 best in Latin America. It has 76 research units, including institutes, centres, stations and experimental farms that allow the generation of knowledge in all areas of knowledge of the institution, Engineering, Sciences, Social Sciences, Health, Agro-food Sciences, Arts and Letters. Part of this knowledge is published in 50 academic journals. It also has a radio station, a television channel and a written newspaper to make its findings available to the public in a clear and simple way.

The UCR promotes research to ensure that the needs of Costa Rican society are met, so that decision-making and the well-being of citizens towards their personal, professional, social and economic development goals are achieved through science and knowledge. Thus, its guiding principles are:

1. Respect for diversity in research and forms of dissemination/dissemination.
2. Promotion of quality and excellence in research.
3. Promotion of multi/transdisciplinary research with the capacity to convene and dialogue with diverse social actors.

The University of Costa Rica is committed to environmental restoration, the generation of clean technologies, gender equity, innovation and entrepreneurship.

30% OFF

CABI

Third International Congress of Biological Control (ICBC3)

San José, Costa Rica

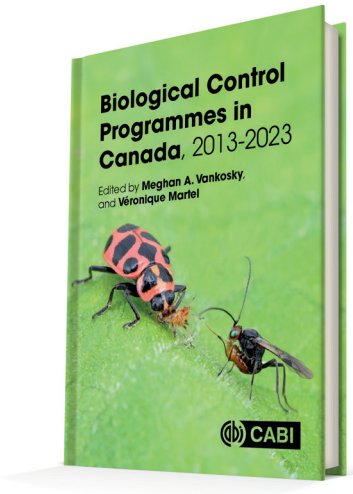
24-27 June 2024

30% discount on **all** books, e-books or individual book chapters through the **CABI Digital Library** until 31 July 2024 – **use the code CON30**

The CABI book publishing programme covers the life sciences and sustainable development. CABI books provide key resources for study, practice and professional development. Recent publications include:

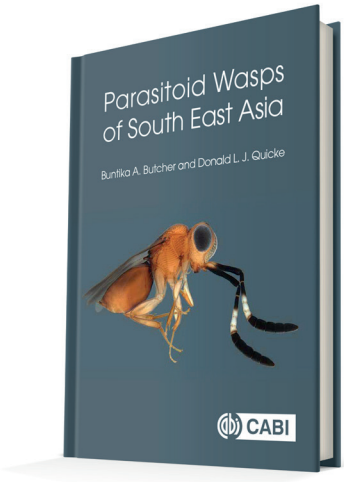
Biological control in Latin America and the Caribbean: its rich history and bright future

J. C. van Lenteren, V. H. P. Bueno, M. G. Luna, Y. C. Colmenarez



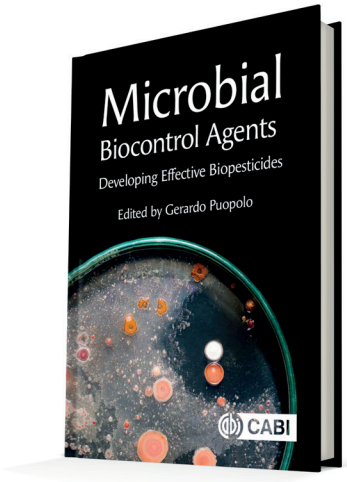
Biological Control Programmes in Canada, 2013-2023

Meghan A. Vankosky, Veronique Martel



Parasitoid Wasps of South East Asia

Buntika A Butcher, Donald Quicke



Microbial Biocontrol Agents: Developing Effective Biopesticides

Gerardo Puopolo

cabidigitallibrary.org/books

KNOWLEDGE FOR LIFE

Scientific Programme

Scientific Programme
3nd International Congress of Biological Control, Costa Rica

Time	Monday - 24 June 2024			
09:00	Registration - Foyer Greco		Poster presenters place posters on numbered boards - Room Greco	
10:00		IOBC General Assembly - Room Rivera-Velazquez		
11:00				
12:00				
13:00	Plenary - Room Greco **Opening Session - Room Greco (60 min)** Victor Carvajal, Minister, Ministry of Agiculture & Livestock of Costa Rica Manuel Otero, Director General, Inter-American Institute for Cooperation on Agriculture (IICA) Maria del Milagro Granados, Professor, University of Costa Rica (UCR) Martin Hill, President, International Organization of Biological Control (IOBC) Ulli Kuhlmann, Executive Director - Global Operations, CAB International (CABI)			
14:00	Plenary - Room Greco			
	Plenary Session 1			
14:00	Moderation - Martin Hill			
14:05	Keynote Speaker - Nick Mills: Biological control for One Health (25 min + 20 min discussion)			
14:45	Moderation - Martin Hill			
14:50	Keynote Speaker - Raghu Sathyamurthy: A nod to the past and present, with an eye to the future: advances needed to sustain the next chapter(s) of biological control (25 min + 20 min discussion)			
15:30	Coffee/Tea (45 min) - Foyer Greco Room			
16:15	Plenary - Room Greco			
	Plenary Session 2			
	Moderation - Ulli Kuhlmann			
	What needs to be done to improve the uptake of biological control? A multi-stakeholder perspective - Panellists: Pedro Rocha, Inter-American Institute for Cooperation on Agriculture (IICA); Martin Wohlfarther, International Biocontrol Manufacturers Association (IBMA); Veronica Picado, Minor Use Foundation (MUF); José Campos, Sustainable Agriculutre Network (SAN); and Luis Diego Arroyo Rivera, National Association of Agricultural Organizations, Costa Rica			
18:00	Poster Session - Room Greco (90 min)			
19:30				
20:00	Welcome Reception (included in registration)			
21:30	End Day 1			

Time	Tuesday - 25 June 2024			
08:30	**Plenary - Room Greco**			
	Plenary Session 3			
08:30	Moderation - Ulli Kuhlmann			
08:35	**Keynote Speaker - Tara Gariepy: The use of molecular tools to unravel host-parasitoid associations in biological control of invasive insect pests (25 min + 20 min discussion)**			
09:15	Moderation - Ulli Kuhlmann			
09:20	**Keynote Speaker - Ted Turlings: Herbivore-induced plant volatiles and how they can be exploited for targeted biocontrol (25 min + 20 min discussion)**			
10:00	**Coffee/Tea (45 min) - Foyer Room Greco**			
10:45	**Track 1 - Room Rivera-Velazquez**	**Track 2 - Room Mediterranean-Bali**	**Track 3 - Room Pacific-Atlantic**	**Track 4 - Room Aquamarine**
	Session 1	**Session 2**	**Session 3**	**Session 4**
	Biological control of aquatic weed	**Slotting biological control into the agroecology toolkit**	**Advance of applied biological control in Latin America**	**Free themes**
	Julie Coetzee, Alejandro Sosa & Melissa Smith	Kris Wyckhuys & Lessando Gontijo	Yelitza Colmenarez & Lorena Barra Bucarei	Kent Daane & Belinda Luke
10:45	Moderation	Moderation	Moderation	Moderation
10:50	**Gianmarco Minuti:** Stick to your grubs: a flea beetle to combat the seedling recruitment of *Iris pseudacorus* (Iridaceae), an invasive wetland plant in the Southern Hemisphere	**Kris Wyckhuys**: Unveiling the architecture of biological control	**Joop C. van Lenteren**: 99.9% of the more than 1000 species of natural enemies used in biocontrol in Latin America are safe	**Jorge Jaramillo-Gonzalez**: Exploring the potential for biological control in industrial hemp crops
11:10	**Rodrigo Diaz**: Lessons on recovery: Contrasting the impact of biological control of giant salvinia (*Salvinia molesta*) in tropical and subtropical regions	**Pedro Togni**: Conservation biological control in tropical agroecological farms: the role of landscape and local features	**Tamara Takahashi:** Advances in the application of biological control in Brazil: challenges and opportunities	**Kent Daane**: Releases of the parasitoid *Pachycrepoideus vindemmiae* for augmentative biological control of spotted wing drosophila, *Drosophila suzukii*
11:30	**Megan Reid**: South Africa vs. south Florida: mass rearing and inundative releases of *Megamelus scutellari* s to manage waterhyacinth (*Pontederia crassipes*)	**Jason Schmidt**: Resolving effects of hedging practices on biocontrol communities and trophic interactions	**Pablo Benavides**: Classical biological control for *Hypothenemus hampei* (Coleoptera: Curculionidae) in Colombia using African parasitoids	**Carmelo Rapisarda**: Biological control of whiteflies on protected vegetable crops in Sicily (southern Italy): from illusions to reality
11:50	**Victoria Ayala**: BioControl meets AI: Implementation of real-time satellite monitoring for detection and management of giant salvinia (*Salvinia molesta*)	**Michael Brunner**: Combining an entomopathogenic fungus with crop diversification boosts its control efficacy against an important soil-dwelling pest	**Eduardo Donoso**: Meta-analysis on the consistency in the control efficacy of Bacillus spp. formulation against Alternaria alternata in tomato: results from Chile, Peru, Argentina, Brazil and Mexico	**Angelos Mouratidis**: Pirates to the rescue: expanding the use of *Orius* predators in floriculture
12:10		**Roselyne Labbe**: Stabilizing the agri-food web: The case for apex arthropod predators in the greenhouse	**Fernanda Cingolani**: Biological control programmes in Argentina: an overview	
12:30	**Lunch Break (1h 30 min)**			

	Track 1 - Room Rivera-Velazquez	Track 2 - Room Mediterranean-Bali	Track 3 - Room Pacific-Atlantic	Track 4 - Room Aquamarine
	Session 5	**Session 2**	**Session 3**	**Session 4**
14:00	**Risk assessment procedures for the safe import, quarantine rearing, and release of biocontrol agents against weeds and pests**	**continued**	**continued**	**continued**
	Laura Varone & M. Belen Aguirre			Giselher Grabenweger & Kate Constantine
14:00	Moderation	Moderation	Moderation	Moderation
14:05	**Iain Paterson**: Selecting the most damaging biocontrol agents for invasive alien Cactaceae in sub-Saharan Africa	**Samantha Willden**: Recruiting biocontrol agents to high tunnel tomato: companion plants vs. Weeds	**Francisco Gonzalez**: Parasitoids at work! An applied 6-years account of the use of *Spalangia endius* for the control of *Stomoxys calcitrans* in coffee wastewater management	**Anna Spescha**: When competitors join forces: using consortia of entomopathogenic *Pseudomonas bacteri* a, nematodes and fungi for pest control
14:25	**Dean Brookes**: Cogongrass (*Imperata cylindrica*) diversity and native range exploration for herbivores	**Helda Morales**: Promoting a preventive lens for biological control in agroecosystems	**Adriana Acevedo Alcalá**: First record of *Anagyrus tristis* (Hymenoptera: Encyrtidae) in Mexico and its potential for biological control of *Phenacoccus madeirensis* (Hemiptera: Pseudococcidae)	**Juliane Ferreira**: Biocontrol sweet spot: stepwise screening toward the identification of bacteria protecting strawberries from *Phytophthora cactorum* root and crown rot
14:45	**Greg Wheeler**: Biological control of the invasive grass cogongrass, *Imperata cylindrica*	**Arletys María Verdecia Mogena**: Maize direct response to entomopathogenic nematodes	**Alyssa Gooding**: Risk assessment status of a potential biological control agent of the Avian Vampire Fly in Galapagos	**Maria Zwyssig**: Insecticidal pseudomonads – interspecies interactions and adaptation to insect larvae
15:05	**Maria Belen Aguirre**: Exploring the safety of two parasitoid candidates for the biological control of the cactus mealybug *Hypogeococcus* sp. in Puerto Rico	**Lessando Gontijo**: Incentivizing biocontrol use in agroecological systems by extending the benefits beyond pest control	**Gerardo Arias-Robledo**: Controlling an emerging pest in Mexican horticulture: can we consider *Trissolcus basalis* for controlling the Mexican Stink Bug *Euschistus rugifer* ?	
15:25	**Laura Varone**: Assessing the potential of parasitoids as biocontrol agents for the Cactus Moth, *Cactoblastis cactorum* in Argentina and North America		**Saúl Aguirre**: Risk assessment of the parasitoid *Conura annulifera* as a biological control agent of *Philornis downsi* in the Galapagos Islands	**Lara Maistrello**: Side effects of cyantraniliprole and neem-based insecticides on *Myzus persicae* biocontrol agents
15:45	**Coffee/Tea (30 min) - Foyer Room Greco**			
	Track 1 - Room Rivera-Velazquez	**Track 2 - Room Mediterranean-Bali**	**Track 3 - Room Pacific-Atlantic**	**Track 4 - Room Aquamarine**
	Session 6	**Session 7**	**Session 8**	**Session 9**
16:15	**Molecular tools in biological control**	**Pre-emptive biological control: a novel approach to increase preparedness for potential biosecurity threats**	**Use and preservation of parasitoids in agriculture: challenges and potential**	**Biocontrol in a changing world! Develop and broadcast biocontrol strategies resilient to climate change and biodiversity loss**
	Tara Gariepy & Jason Schmidt	Gonzalo Avila & Jana Collatz	Matthew Tinsley & Yelitza C. Colmenarez	Michelle Fountain & Liam Harvey
16:15	Moderation	Moderation	Moderation	Moderation
16:20	**Mélodie Ollivier**: How ecological networks revealed by DNA metabarcoding may help in biological control programs? The case study of *Sonchus oleraceus* in Australia	**Gonzalo Avila**: Pre-emptive classical biocontrol risk assessment for high-risk biosecurity threats: paving the way for implementation	**Margot Gumbau**: Parasitoid wasps recruitment by flowering plants for natural regulation of Diaphania sp. in cucumber cropping systems in the Caribbean	**Giselher Grabenweger**: How to control a regulated invasive pest in a sustainable way? The case of *Popillia japonica* in continental Europe
16:40	**Stephanie Chen**: PhyloControl: a phylogeny visualisation interface for risk analysis in weed biological control	**Ricky Lara**: Challenges and opportunities: implementing pre-emptive biological control in California	**Alejandro Tena**: Can we manage honeydew to preserve parasitoids and increase their biological control services?	**Chris McGrannachan**: Biocontrol initiatives for invasive weeds in the Pacific
17:00	**Brandi Misiaszek**: Applying novel primers as a tool for determining the Ligustrum Weevil's (*Ochyromera ligustri*) impact on invasive Chinese privet	**Jana Collatz**: Assessing the feasibility of pre- emptive biocontrol against the emerald ash borer – a European case study	**Rodrigo Maciel**: Use and preservation of parasitoids in agriculture: challenges and potential	**Rebecca Boulton**: Can cryptic sex enhance the performance of an asexual aphid parasitoid?

17:20	**Jason Schmidt**: Molecular diagnostics reveal both landscape pattern effects and functional redundancy in whitefly- predator food webs	**Marc Kenis**: Classical biological control of the Japanese beetle, *Popillia japonica* , in Europe using the tachinid fly *Istocheta aldrichi*	**Gaylord Desurmont**: Use of *Diadegma semiclausum* as a biocontrol agent against diamondback moth in California: potential and challenges	**Norbertas Noreika**: Pesticide-induced food and macronutrient limitation in beneficial carabid beetles in agroecosystems
17:40	**Philippe Belliard**: Tillage effects on trophic interactions in carabid communities and their implications for biological control	**Marco Molfini**: Assessing the potential of native *Anastatus* spp. (Hymenoptera: Eupelmidae) parasitoids for proactive biological control of *Lycorma delicatula* in California	**Ángel Plata**: Unravelling the factors determining the efficacy of mealybug parasitoids	
18:00	**Venkatesan Thiruvengadam**: Potential RNA mediated control of global pest, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae)	**Mari West**: Is *Anastatus reduvii* (Hymenoptera: Eupelmidae) a potential natural enemy for proactive biological control of the spotted lanternfly in California?	**Jesica Pérez-Rodríguez**: Virome of the citrus mealybugs *Planococcus citri* , *Delottococcus aberiae* and their parasitoids: potential implications for biological control	
18:20		**Pablo Lopez Carretero**: Could biotic resistance contribute to future biological control efforts for brown marmorated stink bug (BMSB) in Aotearoa New Zealand?		
18:40	**End Day 2**			

Time	Wednesday - 26 June 2024			
08:30	**Plenary - Room Greco**			
	Plenary Session 4			
08:30	Moderation - George Heimpel			
08:35	**Keynote Speaker - Tania Zaviezo: Mind the gap: mechanisms in conservation biological control (25 min + 20 min discussion)**			
09:15	Moderation - George Heimpel			
09:20	**Keynote Speaker - Ralf-Udo Ehlers: Role of biocontrol for transformation of agricultural practice (25 min + 20 min discussion)**			
10:00	**Coffee/Tea (45 min) - Foyer Room Greco**			
10:45	**Track 1 - Room Rivera-Velazquez**	**Track 2 - Room Mediterranean-Bali**	**Track 3 - Room Pacific-Atlantic**	**Track 4 - Room Aquamarine**
	Session 10	**Session 11**	**Session 12**	**Session 4**
	Mechanism in conservation biological control	**Trajectory of commercial biological control in North America and Europe**	**Invasive alien grasses as targets for weed biological control**	**continued**
	Tania Zaviezo, Simone Mundstock Jahnke & Yelitza Colmenarez	Lynn M. LeBeck	Iain Paterson, Greg Wheeler & Guy Sutton	Alejandro Tena & George Heimpel
10:45	Moderation	Moderation	Moderation	Moderation
10:50	**Felix Wäckers**: *Pronematus ubiquitus* : a multitasking mite for pest and disease control	**Suzanne Lommen**: Genetics of pest control agents: to what extent do they matter?	**Brian Rector**: Biocontrol of annual grasses associated with Wildfire in North America	**Pablo Urbaneja Bernat**: Plant guttation a potential nutrient- rich food source for insects in peach
11:10	**Simone Mundstock Jahnke**: The IOBC-NTRS Conservation Biological Control working	**Norman Leppla**: Advancing commercial biological control in North America through advocacy and education	**Francecsa Marini**: Exploring the potential of eriophyid mites in biological control of annual grasses	**J.P. Michaud**: Conservation biological control under threat on the High Plains
11:30	**Bruno Jaloux**: Elicitor based Attract and Reward strategy against *Dysaphis plantaginea* in apple orchards	**Lynn LeBeck**: Current trends in commercial biological control in North America	**Chantal Probst**: Investigating the floral smut *Ustilago quitensis* as a potential biocontrol agent against pampas grass in New Zealand	**Matt Tinsley**: Impacts of biostimulant application on the efficacy of parasitoid-based biological control in tomato horticulture
11:50	**Tania Zaviezo**: Accessibility, availability and nutritional value of native flowers from central Chile to *Mastrus ridens* (Hymenoptera: Ichneumonidae), a natural enemy of codling moth	**Martin Wohlfarter**: Macrobial regulation within Europe - a comparison	**Colin Morrison**: Tri-trophic plant-herbivore- parasitoid assemblages and diet breadth across native and introduced grasses	**Enric Vila**: A unique combination of prey mites as supplementary food to boost the predators
12:10	**Betty Benrey**: Milpa farming: fostering biological control in a traditional Mesoamerican agricultural system	**Carol Glenister**: Developments in new commercial biological control products and delivery methods	**Guy Sutton**: Biological control of invasive African grasses: progress and prospects	**Raghavendra Reddy Manda:** Plant-mediated effects of yellow mealworm waste on the brown marmorated stink bugs: A potential contribution to IPM

12:30	Lunch Break (1h 30 min)			
	Track 1 - Room Rivera-Velazquez	**Track 2 - Room Mediterranean-Bali**	**Track 3 - Room Pacific-Atlantic**	**Track 4 - Room Aquamarine**
	Session 10	**Session 11**	**Session 13**	**Session 4**
14:00	**continued**	**continued**	**Biocontrol and climate change: challenges and adaptation**	**continued**
			Joan van Baaren & Yelitza Colmenarez	Léna Durocher-Granger & Malvika Chaudhary
14:00	Moderation	Moderation	Moderation	Moderation
14:05	**Leonardo Fabio Rivera Pedroza**: Conservation strategies applied in Sugar Cane in Colombia: a successful case	**David Haviland**: Enhanced conservation biocontrol using commercial-scale hydrogel baiting strategies for sugar-feeding ants in California vineyards	**Paul Ode**: Climate change, plant defenses, and consequences for biological control	**Andreas Walzer**: The predation success of *Phytoseiulus persimilis* on its preferred prey, the spider mite *Tetranychus urticae*, is strongly reduced under extreme heat stress
14:25	**Elizabeth Lamb**: Encouraging the adoption of conservation biocontrol by farmers and the public using beneficial habitat plots	**Juliette Pijnakker**: Biological control of the tobacco thrips *Thrips parvispinus* (Karny)	**Gang Ma**: Biocontrol, climate change and population dynamics: Why is an increase of pest outbreaks and plant diseases transmitted by vectors expected following climate changes?	**Ikkei Shikano**: A novel formulation of entomopathogenic fungi that facilitates horizontal transfer of spores and improves long-term viability in bait stations
14:45	**Juan Antonio Sanchez**: Conservation of natural enemies provides satisfactory control of pear psyllids in Mediterranean pear orchards	**Sheng Qiang**: Development of *Bipolaris yamedae* into a potential bioherbicide against paddy weeds	**Honest Machekano**: Thermal performance drifts between egg-parasitoid and its host may threaten the efficacy of biological control of a global pest	**Nancy Chaves**: Bioprospecting of microorganisms for the management of the bacteria *Ralstonia solanacearum* Race 2, causal agent of Bacterial Wilt Disease (Moku) in banana
15:05	**Bruno Zachrisson**: Weeds associated with rice crop (*Oryza sativa* L.), as a refuge of *Telenomus podisi* for the reduction of the population of *Oebalus insularis* : a conservative control in a tropical agroecosystem	**Thomas V. M. Groot**: Biological control of invasive species using known natural enemies	**Adriana Najar-Rodriguez**: Effects of CO2 and heatwaves on trophic interactions mediating biological control systems	**Léna Durocher-Granger**: Modeling mortality factors and natural enemies of fall armyworm in Zambia
15:25		**Eduardo Donoso**: Biocontrol strategy for the complete cycle of Lasiodiplodia theobromae in avocado through Trichoderma spp formulation sprays on foliage and litter: results from Chile, Peru and Mexico	**Joan van Baaren**: Biological control systems and climate change	**Elena Romero**: Functional response and host stage preference of mealybug parasitoids of the genus *Anagyrus*
15:45	Coffee/Tea (30 min) - Foyer Room Greco			

16:15	Track 1 - Room Rivera-Velazquez	Track 2 - Room Mediterranean-Bali	Track 3 - Room Pacific-Atlantic	Track 4 - Room Aquamarine
	Session 14	**Session 15**	**Session 16**	**Session 17**
	Raising awareness for action: country perspectives on community engagement and what it means for those researchers	**Targeting biological control traits for improvement: challenges and future directions**	**Enhanced biodiversity at landscape level for sustainable management of crop pest**	**Progress on the biological control of foodborne and plant pathogens of agricultural commodities**
	Kim Weaver, Grant Martin, Lorena Barra Bucarei & Malvika Chaudhary	Kelley Leung & Leo W. Beukeboom	Feng Zhang & Oliver Bach	Modesto Olanya & Ade Oladeinde
16:15	Moderation	Moderation	Moderation	Moderation
16:20	**Tamara Takahashi:** Public-private initiatives to reinforce the research and increase the use of biological control in Brazil – SPARCBio case study	**Ryan Paul**: Applications of life history theory in biological control	**Amit Kumar**: First report of *Brachymeria* spp. (Hymenoptera: Chalcididae) as a Hyperparasitoid on *Charops bicolor* Szepligeti (Hymenoptera: Ichneumonidae) an larval parasitoid of *Spodoptera frugiperda*	**Ranajit Bandyopadhyay:** Bridging research to practice: Scaling aflatoxin biocontrol products through public private partnerships
16:40	**Kim Weaver**: Promoting biological control leads to improved implementation and long- term sustainability?	**Leo W Beukeboom**: Trait selection in biocontrol agents - a review	**Manuel Zumbado**: Multifunctional margins for enhancing biodiversity in agroecosystems	**Adelumola Oladeinde**: Application of probiotics as a biocontrol for Salmonella in chicken
17:00	**Yelitza Colmenarez**: Collaboration platforms and public-private initiatives favouring the uptake of biological control - case studies from Latin America	**Marianna Szucs**: Biological control potential of a laboratory selected generalist parasitoid versus a co-evolved specialist parasitoid against the invasive *Drosophila suzukii*	**Oliver Bach**: Practical considerations for the establishment of habitat islands for natural enemies – the case of oil palm in Malaysia	**O. Modesto Olanya**: Application of competitive microbes, predatory bacteria and antimicrobials for biocontrol and inactivation of foodborne pathogens
17:20	**Malvika Chaudhary**: Digital support tools: catalysing the uptake of bioprotection products through technological interventions	**Kelley Leung**: How hard is it to improve a biocontrol trait? A case of parasitoid host specificity	**Chengyun Li**: Agrobiodiversity for sustainability of crop pest management	**Daniel Mendoza Jiménez**: Organic tomato crop management by a bio-formulation based on PGPR: its effects on beneficial plant development and protection against vascular wilt disease
17:40	**Grant Martin**: Resolving conflict situations when using biological control against economically-useful invasive tree species	**Sara D Arco**: Molecular, taxonomic and behavioral characterization of house fly parasitoids in northern Italy	**Audrey Grez**: Landscape composition and heterogeneity affects the abundance and diversity of coccinellids, and biological control in alfalfa fields in Central Chile	**Ranajit Bandyopadhyay**: Regulatory approval of bioprotectants: lessons from registering multiple aflatoxin biocontrol products in Africa
18:00	**Lorena Barra-Bucarei**: Development and technological transfer model of bioinputs based on endophytic microorganisms	**Angela Saenz**: Classical biological control of the Emerald Ash Borer, an invasive forest pest of North America: challenges, management, and assessment of success		
18:20		**Michael Rostás**: Ecological functions and intraspecific variability of *Trichoderma sesquiterpenes* and other volatiles		
18:40	**End Day 3**			
20:00	**Congress Dinner (tickets to be booked during online registration process)**			

Time	Thursday - 27 June 2024			
	Track 1 - Room Rivera-Velazquez	**Track 2 - Room Mediterranean-Bali**	**Track 3 - Room Pacific-Atlantic**	**Track 4 - Room Aquamarine**
	Session 18	**Session 19**	**Session 20**	**Session 4**
8:30	**Recent advances in the classical biological control of alien invasive insects in sub-tropical Africa**	**Biocontrol of plant diseases: efficacy, durability and integration**	**Use of microbials as biological control agents in sustainable agriculture**	**continued**
	Ivan Rwomushana & Marc Kenis	Marc Bardin & Jürgen Köhl	Lorena Barra Bucarei, Yelitza Colmenarez, Daohong Jiang & Jiatao Xie	Chandra Moffat & David Ensing
08:30	Moderation	Moderation	Moderation	Moderation
08:35	**Marc Kenis**: Importance of host specificity in classical biological control against insect pests threatening livelihoods	**Marc Bardin**: How to manage the complexity of deploying microbial biocontrol agents against plant diseases?	**Daohong Jiang**: Exploration of mycoviruses-mediated hypovirulent strain as plant vaccine to control fungal diseases of field crops	**Chandra Moffat**: Post-introduction redistribution of biological control agents: best practices, risks and benefits
08:55	**Ivan Rwomushana**: Classical biological control for the sustainable management of papaya mealybug (*Paracoccus marginatus)* in East Africa	**Jürgen Köhl**: Challenges in using microbial antagonists on seeds to protect seedlings from diseases	**Matt Tinsley**: Selectivity of microbial biopesticides in crop protection	**David Ensing**: Incongruent range limits of invasive spotted knapweed (*Centaurea stoebe* ssp. *micranthos*) and key biological control agents results in high elevation refugia
09:15	**Khalid Khfif**: Investigation, identification and study of the effectiveness of the natural enemies against the leafhopper *Jacobiasca lybica* (Hemiptera: Cicadellidae) under laboratory conditions	**Magnus Karlsson**: Breeding for biocontrol: Exploring genetic variation in biocontrol interactions	**Jiatao Xie**: Plant modifies fungal non-self recognition to facilitate mycovirus transmission	**Martin Hill**: Agents sans frontiers: cross border aquatic weed biological control
09:35	**Frank Chidawanyika**: Controlling the fall armyworm using the push-pull strategy: trophic interactions and the potential for classical, and augmentative biocontrol for improved field efficac	**George Karaoglanidis**: Use of *Bacillus amyloliquefaciens* QST713 and *Clonostachys rosae* IK726 to control multidrug resistant strains of *Botrytis cinerea*	**Belinda Luke**: The use of *Metarhizium rileyi* to control fall armyworm in Zambia	**Javiera Ortiz-Campos**: Potential of endophytic *Beauveria* spp. for growth promotion in blueberries and protection against *Neofusicoccum parvum* disease
09:55	**Sahadatou Mama Sambo**: Management of *Phthorimaea absoluta* with introduced and native biocontrol agents	**Sharon Badilla Arias**: Enterobacter cloacae and a bacteriophage of the pathogen *Erwinia tracheiphila* as biocontrol agents of cucurbit bacterial wilt of muskmelon	**Beilei Wu**: Effects on the sporogenesis and biocontrol functions of *Trichoderma* spp. by the mycoviruses	**Pablo Garcia Palacios**: Arbuscular mycorrhizal fungi and soil organic carbon as tools to enhance crop yield
10:15	**Coffee/Tea (30 min) - Foyer Greco Room**			
	Track 1 - Room Rivera-Velazquez	**Track 2 - Room Mediterranean-Bali**	**Track 3 - Room Pacific-Atlantic**	**Track 4 - Room Aquamarine**
	Session 21	**Session 22**	**Session 20**	**Session 23**
10:45	**Modeling biological control interactions in support of agriculture and conservation**	**Socio-economics of biological control**	**continued**	**The importance of IPM adoption for biological control success**
	George Heimpel	Justice Tambo & Beatrice Muriithi		Matthew Tinsley & Yelitza C. Colmenarez
10:45	Moderation	Moderation	Moderation	Moderation
10:50	**Paul Ode**: Trait-based approaches to predicting biological control success: challenges and prospects	**Steven Naranjo**: Synthesis of the global economic impact of classical and conservation arthropod biological control	**Lorena Barra-Bucarei**: Collection of endophytic nematophagous strains and their potential in the control of phytoparasitic nematodes in tomato	**Rose Buitenhuis**: Old and new thrips species causing trouble: adjusting greenhouse biocontrol programs to manage multiple thrips species
11:10	**Saskya van Nouhuys**: Dynamic economic thresholds for insecticide applications against agricultural pests: Importance of pest and natural enemy migration	**Beatrice Wambui Muriithi**: Economic impact of a classical biological control program: application to *Diachasmimorpha longicaudata* against *Batrocera dorsalis* fruit fly in Kenya	**Edward LeBrun**: Biological control of tawny crazy ants with the microsporidian pathogen *Myrmecomorba nylanderia* e: the need for a Central American program	**Samantha Willden**: The intersection of weed management, biopesticides, and biological control to manage aphids on winter crops
11:30	**George Heimpel**: A new framework for benefit-risk analysis for biological control introductions	**Justice Tambo**: Adoption and impact of bioprotection products in Bangladesh	**Lucía Noboa-Jiménez**: Distribution of *Trichoderma rifaii* CT5 colonization in coffea arabica: insights into plant-endophyte dynamics	**Alessandra Marieli Vacari**: IPM and biological control in coffee

11:50	**Alberto Mele**: The joint action of *Trissolcus japonicus* and *Trissolcus mitsukurii* in biological control of *Halyomorpha halys* in Italy	**Kate Constantine**: Perceptions and willingness to use biological controls for fall armyworm in Zambia, a gendered perspective		**Marcel Tanner**: Multiple effects of baculoviruses and their use in IPM strategies
12:10	**Margarita Correa**: Modeling the interactions of *Pseudococcus* biological control agents on vineyards and its implications in virus spread	**Malvika Chaudhary**: Local biopesticide production hubs – insights on business models and evidence of women's empowerment from Bangladesh and India		**António Onofre Soares**: Ecological and economic feasibility of mass production of biological agents to control tomato moth, *Tuta absoluta* (Meyrick) (Lepidoptera, Gelechiidae) in protected culture
12:30				**Ruth Carter**: Coexistence and competition of two armyworms and implications for IPM
12:30	**Lunch Break (1h 30 min)**			

	Track 1 - Room Rivera-Velazquez	Plenary - Room Greco
14:00	**Session 4**	**Poster Session - Room Greco (75 min)**
	continued	
	Ulli Kuhlmann & Feng Zhang	
14:00	Moderation	
14:05	**Shanshan Li**: Develop synthetic biology-based platform for efficient biomanufacturing of natural product pesticides from *Streptomyces* species	
14:25	**Yuyan Li**: Mass rearing, storage and application of natural enemy insects	
14:45	**Yibo Zhang**: Evaluation of the potential biocontrol ablity of a native natural enemy, *Nesidiocoris poppiusi* , against *Tuta absoluta* in China	
15:05	**Joseph Mulema:** Sustainable Access and Benefit-sharing of biological control genetic resources for classical biological control: a case for Kenya	
15:15	**Coffee/Tea (45 min) - Foyer Room Greco**	
16:00	**Plenary - Room Greco**	
	Plenary Session 5	
	Biological control in a national and international policy context	
16:00	Moderation - Andy Sheppard, Martin Hill & Raghu Sathyamurthy	
16:10	**Andy Sheppard**: Biological control is considered high risk by most governments around the world - how do we address this?	
16:30	**Hariet L. Hinz**: Classical biological control in Europe: regulatory constraints and how to move forward	
16:50	**Michelle Rafter**: Further integrating weed biological control into the Australian policy context – the development and implementation of a National Pipeline Strategy	
17:10	**Martin Hill:** Classical biological control in Africa: constraints and opportunities	
17:30	Discussion	
18:00	**Closing Address by the President of IOBC, Martin Hill**	
18:15	**End Day 4**	

Poster Presentations

Poster #	Session Code	Author Name	Poster Title
1	01-P01	David Ensing	First report of native waterlily leaf beetle (*Galerucella nymphaeae* , Coleoptera: Chrysomelidae) feeding on invasive parrot's feather watermilfoil (*Myriophyllum aquaticum* , Haloragaceae) in Canada
2	02-P01	Fernanda Cingolani	Assessment of a tachinid fly and an egg parasitoid as biocontrol agents of *Edessa meditabunda* (Hemiptera: Pentatomidae)
3	02-P02	Daniel Cormier	Mixture of Btk and the granulovirus CpGV reduces codling moth control
4	02-P03	Arletys María Verdecia Mogena	Maize direct response to entomopathogenic nematodes
5	02-P04	Leslie Aviles	Evaluating biorational products effects on twospotted spider mite and predatory mites under high tunnels-simulated conditions
6	03-P01	Miguel Zapater	Insectarios SRL: the first biological control supplier in Argentina
7	03-P02	Karina Carrera	Evaluation of the antagonistic activity of *Trichoderma* spp. versus *M. roreri* in the Ecuadorian Amazon
8	03-P03	Segundo Valle Ramírez	Pathogenicity of four native isolates of *Beauveria bassiana* ((Balsamo) Vuillemin) against adults of *Metamasius hemipterus* L. in Pastaza, Ecuador
9	03-P04	Renato Gonçalves Santos Neto	Virulence of entomopathogenic fungi to *Disonycha glabrata* (Fabricius, 1775) (Chrysomelidae: Alticinae)
10	03-P05	Dunia Chávez Esponda	Study and identification of mitesof the Phytoseiidae family using computer applications
11	03-P06	Jesus E. Gomez	Has *Cephalonomia stephanoderis* , an introduced parasitoid of CBB, become very abundant almost 10 years after its release in Puerto Rico?
12	03-P07	Franceli Da Silva	*Lippia alba* hydrosol in the control of *Fusarium* spp. in papaya
13	03-P08	Franceli Da Silva	Hydrosol potential of *Mimosa verrucosa* benth leaves in the control of *Aspergillus welwitschiae*
14	04-P01	Jerome Grant	Lessons learned: successes, limitations, and opportunities for classical biological control in the southern U.S.A. (Tennessee)
15	04-P03	Angelos Mouratids	Evaluating predatory mites for the control of *Scirtothrips* in strawberry; from the lab to the field
16	04-P04	Jacques Brodeur	Oviposition determinants in *Istocheta aldrichi* (Diptera: Tachinidae), a parasitoid of the Japanese beetle
17	04-P05	Sara D Arco	Field monitoring of houseflies and their parasitoids in dairy farms in northern Italy
18	04-P06	Christopher Dunlap	Taxonomic and genomic diversity of a worldwide collection of entomopathogenic fungi
19	04-P07	Chandra Moffat	First detection of the broad-nosed knapweed seed head weevil, *Bangasternus fausti* (Coleoptera: Curculionidae) in Canada
20	04-P08	Juana Margarita Martínez De Jesús	Isolation of endophytic fungi in Cuernavaca, Morelos for the control of rust (*Hemileia vastatrix*) in coffee cultivation
21	06-P01	Tatiana Syrovets	Phytochemical composition of *Commiphora oleogum* Resins with insecticidal activities

22	07-P01	Xiaoqing Xian	Estimation of the global biocontrol potential of two native parasitoids *Chelonus insularis* and *Eiphosoma laphygmae* against the fall armyworm
23	08-P01	Weidson Sutil	Use of egg parasitoids in fall armyworm *Spodoptera frugiperda* augmentative biological control: challenges and opportunities
24	08-P02	Joao Gabriel Cancelliero	*Euschistus heros* egg parasitoids: effect of host egg age and collection site
25	08-P03	Alexandre Diniz	Rearing optimization of *Callosobruchus maculatus* , an alternative host for boll weevil parasitoids
26	08-P04	Feng Zhang	Is *Anastatus japonicus* an effective biological control agent against brown marmorated stink bug?
27	08-P05	Tamara Akemi Takahashi	Nonreproductive effects are more important than parasitism in *Trichogramma* spp.?
28	09-P01	Xing Ping Hu	A unique case of successful control of an invasive pest: self-introduced exotic parasitic wasps shifterd attempted classical biocontrol to conservation biocontrol
29	10-P01	Carolina Calderón Arroyo	Effect of the extrafloral nectar of Senna cernua Balb. H.S. Irwin & Barneby (Fabaceae) on the survival of the coffee leaf miner parasitoid *Proacrias coffeae* Ihering (Hymenoptera: Eulophidae)
30	10-P02	Benjamin Yguel	Does a conservation biological control strategy modify the density dependent relationship between aphids and hoverflies?
31	10-P03	Carlos Vásquez	Conservation practices for the enhance of predatory mites: opportunities and challenges
32	10-P04	Rozimar de Campos Pereira	Entomopathogenic fungi in eucalyptus plantation areas on the northern coast of Bahia, Brazil
33	14-P01	Dora Shimbwambwa	Farmer biopesticide for fall armyworm management in Zambia
34	14-P03	Alison Westwood	Inspiring interest in insects – discovery through play
35	15-P01	Elena Romero	Does parasitism in adult stages of female mealybugs prevent oviposition of the pest host? The case of citrus mealybug *Delottococcus aberiae* and its parasitoid *Anagyrus aberiae*
36	15-P02	Kelley Leung	Fine-scale mapping and comparative genomics link parasitoid *Nasonia host preference 1* to an odorant receptor-enriched region
37	15-P03	Lara Maistrello	Parasitization activity of *Spalangia cameroni* and *Muscidifurax zaraptor* (Hymenoptera, Pteromalidae), pupal parasitoids of *Musca domestica* (Diptera, Muscidae)
38	16-P01	Audrey Grez	Landscape composition and heterogeneity, at different spatial scales, filters functional traits and modulate coccinellid communities in alfalfa
39	16-P02	Juan Antonio Sanchez	Multivarieties and cover crops to increase sustainability of Mediterranean pear orchards
40	18-P01	Kate Constantine	Smallholder farmers' knowledge, attitudes and practices towards biological control of papaya mealybug in Kenya
41	18-P02	Mariana Campolino	Stability evaluation of formulations based on the entomopathogenic fungus *Beauveria bassiana*
42	19-P01	Juliane Ferreira	Biocontrol sweet spot: stepwise screenings toward the identification of bacterial strains protecting strawberries from *Phytophthora cactorum* root and crown rot
43	19-P03	Ángela María Mogollón-Ortiz	Actinobacteria, natural enemies of the root-knot nematode *Meloidogyne javanica*

44	20-P01	Luciana Vitorino	Potential of the extract obtained from *Aspergillus nomiae* for the biocontrol of *Spodoptera frugiperda*
45	20-P02	Reyes Alejandro Garnica-Zapata	Co-application of biochar and soil actinobacteria and its effect on the promotion of plant growth in tomato plants
46	20-P03	Layara Bessa	Potential of beneficial microorganisms present in biodiverse compounds based on Angiorperm and Gymnosperm for foliar protection of *Glycine max*
47	20-P05	Beilei Wu	Transcriptome dynamics underlying chlamydospore formation in *Trichoderma virens* GV29-8
48	23-P01	Weidson Sutil	Biological control as part of the soybean Integrated Pest Management (IPM): the success of a Brazilian programme
49	23-P02	Mª Ángeles Marcos García	IPM by essential oils: hard with aphids, soft with their predators
50	23-P03	Michael Brunner	Adopting mixed cropping systems to foster biocontrol and manage oviposition of a mayor belowground insect pest
51	23-P04	Alberto Mele	Evaluating sub-lethal behavioral effects of plant protection products on *Trissolcus* parasitoid
52	23-P05	Dahise Brilinger	Selectivity of hymenopterans in attractants and traps for monitoring fruit flies

Plenary Sessions

Plenary Session 1 - Keynote Speaker: Nick Mills

Nick Mills completed a BSc in Biological Sciences in 1975 and a PhD on the population ecology of a coccinellid predator of aphid in 1979, both from the University of East Anglia in the UK. After a four-year period as a Cook Junior Research Fellow at Lincoln College, Oxford University he joined CABI in 1982. Following an initial appointment as Head of Forest Entomology at the Swiss Centre, he became Director of the UK Centre in 1988. Soon after he accepted a professorship in entomology/ biological control at the University of California, Berkeley in 1990. He has served both as Chair of the Department of Environmental Science, Policy and Management and as Executive Associate Dean for Research and Extension in the Rausser College of Natural Resources at UC Berkeley, and is currently an Emeritus Professor of Entomology. His research interests bridge the gap between theory and practice in biological control with a focus on the ecology of arthropod predators and parasitoids, the dynamics of biological control systems, and the linkage between importation biological control and invasion biology. He has served in an editorial capacity for six different scientific journals and contributed to both national and international science review panels. During his career at UC Berkeley he received awards for undergraduate teaching and graduate mentorship, as well as for research excellence.

Biological control for One Health

Urs Schaffner[2], George Heimpel[3], Nicholas Mills[1], Beatrice Muriithi[4], Matthew Thomas[5], Yubak GC[6] & Kris Wyckhuys[7]

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Biological control is a biodiversity-driven ecosystem service that has been effectively exploited by mankind since 300 CE. By promoting the natural regulation of pests, weeds, and diseases, it produces societal benefits at the food-environment-health nexus. The concept of 'One Health' provides a uniquely useful paradigm for gauging the broader implications of environmental change while accounting for the interconnections between people, animals, plants, and their shared environment. Disciplinary silos and reductionist approaches hamper our understanding and eventual mitigation of complex issues while the One Health framework underlines how close cooperation between professionals in the human, animal, plant, and environmental health sciences can spawn unprecedented societal benefits. Evidence shows that biological control generates desirable outcomes across all One Health dimensions, mitigating global change issues such as chemical pollution, biocide resistance, biodiversity loss, and habitat destruction. Yet, its cross-disciplinary achievements remain unrecognized. Here we argue that a broader use of biological control can help address multiple One Health challenges with examples of how biological control contributes to each of the four interrelated One Health dimensions, i.e., environmental, plant, animal and human health. We emphasize that in addition to its direct benefits, such as reduced densities of crop pests or vectors of human diseases, there are underappreciated indirect benefits, including reduced environmental pollution, enhanced habitat conservation, and increased human and livestock health. We advocate a system-level, integrated approach to biological control research, policy, and practice. Framing biological control in a One Health context helps to unite medical and veterinary personnel, ecologists, conservationists and agricultural professionals in a joint quest for solutions to some of the most pressing issues in planetary health.

Plenary Session 1 - Keynote Speaker: Raghu Sathyamurthy

Raghu Sathyamurthy completed his bachelor's degree in Zoology (Madras, India; 1996) and his master's in environmental management (Griffith, Australia; 1998), and a PhD in Ecology & Entomology (Griffith, Australia; 2002). His graduate research focused on the ecology and evolution of plant-insect insect interactions where he focused on these dynamics from the insect's perspective. Since 2002 he has been working on the biological control of weeds, with a focus on plant-herbivore interactions principally from the plant's perspective. An empirical and quantitative ecologist, his research interests span invasion dynamics, plant-herbivore interactions, integrated population management, and biological control of invasive species. He endeavours to undertake all his research collaboratively, and in close partnership with end-users of science to ensure the research outputs have the best possible chance to be translated into practical outcomes and, eventually, longer-term impacts. He has served as Associate Editor for Environmental Entomology, Biological Control and BioControl. Raghu currently leads a national research program in Biosecurity within Australia's National Science Agency, CSIRO.

A nod to the past and present, with an eye to the future: advances needed to sustain the next chapter(s) of biological control

Raghu Sathyamurthy[1]

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The intersecting impacts of climate change, increased trade and travel, changing land use patterns, and significant international efforts to reduce the use of chemicals in agricultural and environmental interventions, necessitate sophisticated approaches to mitigating biosecurity risks. Biological control has been a valuable asset in the management of such risks (invasive pests (vertebrate and invertebrate), weeds and diseases) for over a century. While this historical legacy is assured (even if sometimes questioned), sustaining the discipline over the next century will require ongoing efforts to modernise all aspects of the discipline. In this talk, I will highlight some emerging trends and approaches spanning the spectrum of activities in biological control (i.e. target selection, agent selection, risk assessment, post release evaluation, integrated management, regulatory engagement, international conventions governing access and benefit sharing). Some of this will challenge the *modus operandi* in the discipline, but meeting this challenge will be essential to strengthen and advance the future of the discipline and share its benefits globally.

Plenary Session / Discussion 2 - Panellists: Martin Wohlfarter, José Campos Arce & Veronica Picado Pomar

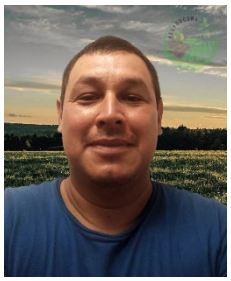
Martin Wohlfarter is a passionate agriculturist with fifteen years global experience in sustainable agricultural pest management. He completed his bachelor's degree in Agricultural Economics and Marketing at the University of Stellenbosch in 2004 and a Post Graduate Diploma in Rural Development and Agrarian Reform at the University of the Western Cape in 2015. Between 2008 and 2018, he worked in the fruit export sector, managed a Sterile Insect Release programme and was a Business Development Manager for the second largest plant protection products' distributer in South Africa. Between 2018 and 2020, he completed an MBA at the Graduate School of Business, University of Cape Town, South Africa. After further exchange studies on Change Management and European Policy, at the Copenhagen Business School, in Denmark, he briefly consulted to CTIFL in Southern France on insect rearing. Since end 2020, Martin is a Regulatory Affairs Specialist at the head office of Koppert B.V. in the Netherlands. He is responsible for global macro product registrations and actively engaged in policy matters, through various industry bodies. He is vice chair of the International Biocontrol Manufacturer Association (IBMA), Macro Professional Group, Rotating Chair of the IBMA Pollinators Group, and Chair of the Artemis Beneficials and Pollinator Group in the Netherlands. Martin will represent IBMA on the panel.

José J. Campos Arce has 40 years of international experience in academic and scientific organizations and technical cooperation, in forestry, agriculture and integrated landscape management. He was director general of Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE), and now serves as the Executive Director of the Sustainable Agriculture Network (SAN), a global impact network that works in the Americas, Africa, Europe, and Asia, orchestrating multistakeholder partnerships with the corporate, academic, and civil society sectors towards making agriculture regenerative. José has served in the boards of international organizations, including CIFOR, ICRAF, IUFRO and in sustainability task forces for The World Bank and the Inter-American Development Bank. José has a doctorate in forestry from the University of Oxford, a master in renewable natural resources management from CATIE/University of Costa Rica and a B.Sc. in forestry from the University of São Paulo, Brazil. He has published over 100 technical and scientific papers.

Veronica Picado Pomar Prior to joining the Minor Use Foundation (MUF), Veronica led the Laboratory for Analysis of Agrochemical Residues in Costa Rica's Office of Sanitary and Phytosanitary matters and oversaw the process of establishing its international accreditation (ISO 17025). She has also served as the Costa Rican delegate to the Codex Committee on Pesticide Residues, the body responsible for setting international pesticide residue standards under the joint hospices of the WHO and the FAO. A chemist by training, she has extensive experience managing studies related to the magnitude of pesticide residues. She now serves as the Foundation's Study Director for Central America and the Caribbean, as well as the Manager for Technical Operations. Veronica will represent MUF on the panel.

Plenary Session / Discussion 2 – Panellists (continued): Pedro Rocha & Luis Diego Arroyo Rivera

Pedro Rocha is a biologist from National University of Colombia, Ph.D. in plant biotechnology and molecular biology from University of East Anglia and John Innes Centre (Norwich, UK). Currently, he works as International Specialist and Coordinator in Biotechnology and Biosafety at the Inter-American Institute for Cooperation on Agriculture (IICA), based in Costa Rica. In this position, he provides technical support (policy generation, training, and communication) in biotechnology and biosafety to the ministries of agriculture of the 34 IICA member countries. His professional experience includes: Postdoctoral Research Scientist at The Sainsbury Laboratory in UK; in Colombia, Researcher at the Program for Agricultural Biotechnology Corpoica (now Agrosavia), Research Assistant at the International Center for Tropical Agriculture (CIAT), Senior Researcher and Director of the Division of Biotechnology at the National Oil Palm Research Center (Cenipalma), Consultant to the National Planning Department (DNP) in biodiversity and biotechnology, and specialist in technology and innovation (IICA). He has technically supported countries to develop regulations on bioinputs (Argentina, Paraguay, Dominican Republic, Guyana) and safety of biotechnology (GM and gene editing). His scientific experience was related to molecular characterization of germplasm, genetic modification of secondary metabolism, and molecular phytopathology. He has been director of 12 undergraduate and graduate works, author of over 160 technical articles, book chapters, technical reports, and press releases, and more than 380 international presentations, and organizer of more than 40 international events on biotech and biosafety.



Luis Diego Arroyo Rivera is an outstanding professional with more than two decades of experience in the agricultural sector. His passion for a healthy planet and his commitment to sustainability were manifested from his youth, when he completed his bachelor's degree in literature at the El Roble Environmental School in Alajuela, Costa Rica. Later, he expanded his academic training by obtaining a Middle Technical degree in Automotive Nautical at the Carlos Luis Fallas Sibaja Professional Technical College, acquiring technical skills that he would later apply in agricultural machinery. With 23 years of experience in agriculture, Luis Diego has specialized in the cultivation of agricultural products that are friendly to humans and the environment, such as tomatoes and sweet chili, crops which are important to Costa Rican restaurants. His innovative approach and refined practices have contributed significantly to improving the quality and yield of these crops, benefiting both producers and consumers. As a business partner of the National Association of Agricultural Organizations, Luis Diego has been a driver of change, promoting the participation of young farmers in agricultural activity. His leadership has inspired a new generation to adopt sustainable agricultural practices and perpetuate agricultural tradition with a modern and environmentally friendly approach. Luis Diego Arroyo Rivera not only grows food, but he actually is also sowing a legacy of innovation, sustainability and prosperity for its community and the country.

Plenary Session 3 - Keynote Speaker: Tara Gariepy

Tara Gariepy completed a BSc at Concordia University, Montreal, Canada, specializing in parasitology and entomology. This was followed by a Masters degree in Pest Management at Simon Fraser University, focusing on epidemiology and molecular diagnostics of plant pathogens. In 2002, she did an internship at CABI-Europe Switzerland on biocontrol of invasive insect pests, which led to her PhD research (2003 – 2007) on the use of molecular tools for non-target risk assessment in biological control (a collaboration between CABI, Agriculture and Agri-Food Canada, and University of Saskatchewan). From 2007 to 2009, she held a NSERC post-doctoral fellowship at University of Hawaii at Manoa, Kauai Agricultural Research Centre, where she conducted research on the use of molecular tools to assess competitive interactions between biocontrol agents of invasive aphids. This was followed by an Ontario Ministry of Research and Innovation post-doctoral award at the University of Guelph and Canadian Centre for DNA Barcoding, on DNA barcoding of parasites and insect vectors of disease. In 2011, she joined Agriculture and Agri-Food Canada as a Research Scientist at the London Research and Development Centre in Ontario. Her research focuses on importation biological control of invasive insects, and development of molecular tools to detect and evaluate trophic interactions between insect pests and their natural enemies.

The use of molecular tools to unravel host-parasitoid associations in biological control of invasive insect pests

Tara Gariepy[1]

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Trophic interactions between hosts and their parasitoids can be difficult to detect and identify using conventional methods, particularly when several closely-related and morphologically similar parasitoids co-exist in the same habitat or on the same host species. Molecular tools can help identify these interactions, which improves our understanding of food web ecology and provides valuable information to guide biological control decisions. Several examples will be presented on how these tools are applied at different stages in the discovery and use of parasitoids in biological control programmes for invasive insect pests.

Plenary Session 3 - Keynote Speaker: Ted Turlings

Ted Turlings did his studies at Leiden University, where he obtained a bachelors and masters degree in Biology, with a specialization in Ecology. In 1985 he moved to the University of Florida to conduct a PhD in Entomology/Chemical Ecology. During his PhD he discovered that insect-damaged plants emit specific volatile signals that attract parasitic wasps. The discovery of herbivore-induced volatiles has led to numerous follow-up studies by dozens of research groups, which resulted in thousands of publications on the topic. After a brief post-doctoral period in Florida, he moved to Switzerland in 1993. He first spent three years at the ETH-Zurich and in 1996 he obtained a prestigious START-fellowship, which he took the University of Neuchâtel to start his own research group. Eventually he was nominated full professor at the same university where he helped to establish the National Centre of Competence in Research *Plant Survival*, a swiss-wide research network that he directed for four years. Currently, he is head of the laboratory of Fundamental and Applied Research in Chemical Ecology (*FARCE*), which focuses on the use of plant-produced signals to improve crop protection. He has received several awards related to the field of chemical ecology and entomology. In 2023 he was elected president of the International Society of Chemical Ecology and was given the Marcel Benoist Prize, Switzerland's most prestigious science award.

Herbivore-induced plant volatiles and how they can be exploited for targeted biocontrol

Ted Turlings[1]

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Natural enemies of herbivorous pests often use plant-provided signals to locate plants that carry potential prey. Particularly intriguing are so-called herbivore-induced plant volatiles (HIPVs), which various plants release in large quantities only when they are attacked by insects (Turlings and Erb, 2018). Aboveground, HIPVs serve as foraging cues for predators and parasitoids, whereas belowground they are exploited by entomopathogenic nematodes. I will present results on our efforts to utilize these plant-produced signals to enhance the efficacy of biological agents. Belowground we have succeeded at making rootworm-damaged maize roots more attractive to entomopathogenic nematodes. Another focus is the use of odor sensors that can be placed on robotic rovers to detect HIPVs in real-time, allowing farmers to determine the presence of specific pests on crops before they do serious harm. The same rovers could then apply biocontrol agents to control these pests, but only when and where it is really necessary.

Turlings, T.C.J. and M. Erb (2018). Tritrophic interactions mediated by herbivore-induced plant volatiles: mechanisms, ecological relevance, and application potential. *Annual Review of Entomology* 63: 433-452

Plenary Session 4 - Keynote Speaker: Tania Zaviezo

Tania Zaviezo did her undergraduate studies at Universidad Catolica de Chile, where she obtained a bachelor's degree in Agricultural Sciences. In 1992 she moved to the University of California at Berkeley (USA) to conduct a PhD in Entomology/Biological Control. During her PhD she studied the evolution of clutch size in gregarious parasitoids and also looked at the interspecific relationships among parasitoids with different life-history traits. From then on, most of her research has explored the question of how biodiversity at different levels, from population genetics to landscapes, influences the outcome of biological control. Upon finishing her Ph.D she returned to Chile, to be an assistant professor at School of Agriculture and Natural Systems, Universidad Catolica de Chile, and in 2011 was nominated full professor at the same university. Here, she leads the laboratory of Fruit Crops Pest Management, which focuses on alternatives to pesticides, such as importation and conservation biological control and the use of pheromones. During her career she has secured funding from competitive national and international agencies, and has collaborated with researchers in many parts of the world. She has also served in many academic positions, such as head of department and vice-dean of undergraduate education, among others. Currently she serves as the secretary for the International Branch of the Entomological Society of America.

Mind the gap: mechanisms in conservation biological control

Tania Zaviezo[1]

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Conservation biological control is an approach that encompasses a diverse set of practices that aim to preserve natural enemies and enhance their activity in order to improve their impact on the pest. It is probably the oldest form of biological control, but relatively new as an area of research. Conservation biological control practices aim to provide complementary or alternative trophic and non-trophic resources, that can be achieved through non-crop habitat/vegetation manipulation; within crop management practices; or direct provision of the resources. Additionally, careful pesticides use in conventional agriculture can be important for conserving natural enemies. Habitat or vegetation manipulation is probably the most studied and used tactic within conservation biological control, ranging in temporal and in spatial scale. Nevertheless, many gaps in knowledge must be addressed before habitat manipulation becomes an effective and more consistent practice, because mechanisms explaining the patterns and effects observed are rarely evaluated. In this talk we will present studies that provide evidence of the mechanisms by which conservation biological control practices increases natural enemies and/or biological control in crops. We will also highlight in which areas of conservation biological control there are the more studies on mechanisms and in which there are more gaps. Finally, we will give some suggestions on how to improve studies in order to move forward in making this strategy more transferable among cropping systems and locations.

Plenary Session 4 - Keynote Speaker: Ralf-Udo Ehlers

Ralf-Udo Ehlers finished his studies in Agriculture in 1985, received his PhD in 1989 and habilitation in 2003. His research focused on the development of liquid culture technology of entomopathogenic nematodes (EPN) at the Institute for Phytopathology of the University Kiel (Uni Kiel), Germany. In 1996, he founded the biotechnology company e-nema, which today is the largest producer of nematodes for biological control of insect pests. From 1988 until 2011, he was first subgroup convenor and then convenor of the IOBC/WPRS Working Group *Insect pathogens and entomoparasitic nematodes*. From 1992 until 2010, he was participating and serving as vice chairman and chairman of several EU COST Actions on EPN and *Bacillus thuringiensis*. Apart from his R&D in EPN he also worked on the use of microbial agents in biocontrol of insects and plant diseases. In 2006/2007, he coordinated the EU Specific Support to Policy Action REBECA: Regulation of biological control agents in Europe. Since 2004 he is guest professor at the University Gent, Belgium and became professor at Uni Kiel in 2009. In 2012, he left Uni Kiel to concentrate on the management of e-nema GmbH. From 2013 until 2018 he served as executive board member and treasurer of the International Biocontrol Manufacturers Association (IBMA) in Brussels lobbying for biological control. From 2014 until 2022, he was president of the European Society of Nematologists. He received the Escherich Award of the German Society for General and Applied Entomology in 2015 and the IBMA Bernard Blum Award for the best biocontrol product of the year 2020 (dianem® for control of the invasive corn pest Western Corn Rootworm). He is honorary member of IBMA. In 2023, he withdrew as shareholder from e-nema and is since working as consultant in biocontrol biotechnology.

Role of biocontrol for transformation of agricultural practice

Ralf-Udo Ehlers[1]

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The world is losing its diversity. In the last 25 years insect biomass has seriously declined. Main driver for insect decline is intensive agriculture (46.6%) followed by invasive species (16.4%), urbanization (10.7%) and deforestation (8.8%). Current agriculture practice heavily depends on synthetic pesticides but at the same time the tool-box of farmers is depleting, particularly with insecticides. Pests develop resistance, older actives are not re-registered, many active ingredients are banned, development of new actives is only possible at high costs and return of investment is declining why innovation is limited and new actives often have a narrow target spectrum. In the near future, agriculture will have to rely on biocontrol biodiversity. This transformation is hampered by a serious lack of knowledge. We know the antagonists but techniques how to promote their potential at farm level is less developed. R&D is needed to develop agro-ecosystem management strategies to enhance the potential of existing antagonists and to introduce and establish those agents, which are missing in the different habitats. Biocontrol industry can support the transition, however, the political environment prohibits the full exploitation of its potentials. Major hurdles are exaggerating data requirements for registration and xenophobic legislation when introduction of non-indigenous species/strains provide more benefits than risks. Externalisation of costs related to the use of synthetic actives would justify the support of biocontrol practice, however, such programmes are rare. Biocontrol industry made significant progress during the last two decades, contributing to a reduction of pesticide residues, substituting synthetic chemicals or filling gaps. How and in which sectors biocontrol industry can support transformation of agricultural practice with less or no insecticides will be demonstrated and discussed. The contribution of novel technologies will be reviewed.

Plenary Session 5 – Keynote Speaker: Andy Sheppard

Andy Sheppard is a Chief Research Scientist in CSIRO. He joined the organisation in France in 1986 having completed his PhD at Imperial College. He is based in Canberra, Australia working in biosecurity and invasive species management. He has been a CSIRO Research Director of three different national programs on plant, animal and environmental biosecurity and terrestrial biodiversity management. His current role is a secondment into the Australian Department Agriculture Fisheries and Forestry as Co-Executive Director of DAFF-CSIRO Catalysing Australia's Biosecurity Initiative after instigating this innovation catalyst as a partnership across both agencies. This $50-$100M Mission was launched in early 2024. He is also the non-residential Director of CSIRO's European Laboratory in Montpellier since 2002. He serves on a number of boards/advisory committees including the OECD Cooperative Research Programme Governing Board and the Scientific Advisory Body, the Federal Government National Biosecurity Committee, the Federal Government Threatened Species Scientific Committee and the CSIRO Centre of Australian National Biodiversity Research. He is also the IUCN Species Survival Commission Focal Person for the IUCN National Committee (NC) of Australia. His portfolio of research projects have included weed, pest and invasive species management based on Australia, South Africa and France. He is a Fellow of the Royal Entomological Society, Australian Academy of Technology & Engineering and an International Fellow of the Académie d'Agriculture de France. In 2023 he was awarded the "L'ordre du Mérite Agricole" by the French Government.

Biological control is considered high risk by most governments around the world - how do we address this?

Andy Sheppard[1]

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Despite more than 100 years of successful use and the generation of effective management of many exotic pests and invasive alien species, classical biological control is still considered high risk by most governments around the world. These are often landlocked countries, where the use of biological control is not common practice and there is little or a lack of policy approaches to regulate its use. This situation is despite the acceptance and promotion of classical biological control as an effective management approach of widespread invasive alien species by the International Plant Protection Convention and the Convention on Biological Diversity. Why is this? In the recent Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Invasive Alien Species Assessment report, the authors covered biological control as a management approach globally in some detail. Countries with no history of science-based and regulated use of classical biological control generally see this approach as encompassing the early and completely unregulated use; for example, the release of cats and mongoose onto islands and cane toads around the world to control pests. This still gives the discipline a bad name despite many studies on the lack on unexpected non-target impacts of biocontrol agent releases. That such governments seem unable to distinguish between such early opportunistic unregulated use and today's highly and regulated application of classical biological control using internationally accepted risk analysis and public consultation, tarnishes the whole modern discipline. The European Union is a good example of this regulator risk aversion despite the increasing use of classical biological control by some EU member countries. This talk analyses the relevant evidence from the IPBES assessment and proposes ways forward to address the current huge lack of global trust in what the science shows is a safe and effective invasive alien species management approach.

Plenary Session 5 – Keynote Speaker: Hariet Hinz

Hariet Hinz did her MSc in Applied Entomology at Imperial College in the UK and her PhD in Biology/Ecology at the University of Fribourg in Switzerland, focusing on plant-insect interactions in relation to classical biological weed control. In 1997, she was employed as a research scientist at CABI in Delémont, Switzerland, and became Head of the Biological Weed Control Programme in 2006. Since 2002, she is also Affiliate Professor at the University of Idaho, USA. She has thus over 30 years of experience in the risk assessment and impact quantification of weed biological control agents and related fields, such as the population biology of plants, invasion ecology and mechanisms underlying the host-finding and host-choice behaviour of insects. She published 65 papers in peer reviewed journals, was co-organizer of the XV International Symposium of Biological Control of Weeds, and co-editor of the most important resource in weed biocontrol 'A World Catalogue of Agents and their Target Weeds'. In 2015, Hariet was appointed Centre Director of the CABI operation in Switzerland, Regional Director in 2020, and Global Director Invasives in 2021. Currently, she is developing, together with colleagues, a new CABI-led programme using an Integrated Landscape Management approach.

Classical biological control in Europe: regulatory constraints and how to move forward

Hariet L. Hinz[1], Tim Haye[1], Marc Kenis[1] & Lukas Seehausen[1]

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Classical biological control (CBC) aims to reduce the density, vigour and spread of exotic invasive organisms (mainly plants and arthropods) by introducing specific natural enemies, so-called biological control agents, from the area of origin of these pests. CBC has been practiced since 100+ years and is characterized by high safety standards. The method has zero negative effects on human and animal health, and minimal to negligible impacts on non-target organisms. Releases of biocontrol agents against invasive plants are fully or partially successful in two out of three cases, leading to benefit:cost ratios of over 3000:1, while releases against invasive arthropod pests are successful in about 40% of cases. Despite the good safety record, and potential for successful control with minimal inputs, CBC, especially against invasive plants, is not commonly practiced in Europe. Many European countries lack regulations to allow the release CBC agents, while others have banned the introduction of exotic natural enemies to control invasive pests altogether. Efforts to try and harmonize regulations for CBC across Europe have failed so far. We will explore reasons for this lack of political will, despite the high demand for alternatives to synthetic pesticides in the face of the European Green Deal and the decrease in registered products. We will also discuss potential ways forward to ameliorate the current situation.

Plenary Session 5 – Keynote Speaker: Michelle Rafter

Michelle Rafter undertook her bachelors, honours and doctoral studies at the University of Queensland, where she obtained a PhD in Evolutionary Ecology in 2013. During her PhD she uncovered the existence of host-specific cryptic species within the taxon *Scirtothrips aurantii*, and that explained the paradox of the host-plant specificity of an adventive "generalist" thrips species to Kalanchoe succulents in Australia. After an intense post-doctoral period in stored product pest research on an India-Australia Grand Challenge Project, Michelle moved to CSIRO in 2016. At CSIRO she has continued to use evolutionary based approaches to develop and apply ecological theory to solving biosecurity problems involving plant-insect interactions. This has led to tangible advances in invasive species management in Australia and globally, through the development of nuanced and innovative approaches to the study of weeds and pest insects. She leads CSIRO's weed biocontrol program with insect candidate biocontrol agents, based in Brisbane, Australia. Michelle has extensive experience in delivering risk analysis under containment for biocontrol agents and weed targets in Australia. More recently, her responsibility has extended to liaising with various government agencies on behalf of CSIRO on weed management and biocontrol strategies. She is currently an Associate Editor for BioControl and Subject Editor for Environmental Entomology, former Associate Editor for Arthropod-Plant Interactions.

Further integrating weed biological control into the Australian policy context – the development and implementation of a National Pipeline Strategy

Michelle Rafter[1], Ben Gooden[2], Mariana Campos[3], Kumaran Nagalingam[1], Gavin Hunter[2], Andrew McConnachie[4], Pete Turner[4], Tony Pople[5], Kunjithapatham Dhileepan[5], Raelene Kwong[6], Jackie Steel[6], Greg Lefoe[5], Shauna Potter[7], Matt Sheehan[7], Peter Brenton[8] & Andreas Glanznig[9]

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[7]Wild Matters Pty Ltd, Castlemaine, Australia
[8]Atlas of Living Australia, Canberra, Australia
[9]The Centre for Invasive Species Solutions, Canberra, Australia

Classical weed biocontrol has been used successfully to control invasive weed species for over 120 years. Weed biocontrol is a proven valuable and effective approach to weed management in Australia with 39% of all programs considered to produce complete or near complete control, 30.5% partial control with an average benefit-cost ratio of 23:1 (Cullen et al. 2022). These successes can be attributed to the exitance of a well-established regulatory pathway and national risk assessment framework that enables biocontrol to be undertaken safely in Australia. But implementation of biocontrol in Australia is at risk due to diminishing agents coming through the research pipeline and variable research investment over time (Sheppard et al. 2023). Since 2014–15, the Australian Government has invested approximately $20 million in weed biocontrol projects, but most of these programs concluded in 2023. In response to this identified risk and to further embed biocontrol into national policy, a National Weed Biocontrol Pipeline Strategy was proposed (Rafter et al. 2022). The aim of this strategy was to ensure that available research investment is allocated to sustain the research pipeline of prioritising weed candidates for research, native range exploration, risk assessment, biocontrol agent release, impact monitoring and evaluation. The strategy was endorsed by the Commonwealth and State governments in 2023 and the initial phase of the strategy commenced in 2024. The development, implementation, and key deliverables of the National Pipeline Strategy will be discussed with the aspiration that the strategy undertaken in the Australian context may prove useful elsewhere.

Plenary Session 5 – Keynote Speaker: Martin Hill

Martin Hill did his undergraduate and postgraduate studies at Rhodes University in South Africa, where he obtained a PhD in entomology in 1995. In 1995 he joined the Plant Protection Research Institute of the Agricultural Research Council of South Africa, where he worked on the biological control of waterweeds, not only for South Africa, but initiated a number of projects throughout Africa. In 2002 Martin rejoined Rhodes University as the Professor of Entomology where he continued his work on waterweeds, but also started developing entomopathogenic fungi and viruses for the control of several crop pests, most notably in the citrus industry. In 2017 Martin established the Centre for Biological Control, which comprises a consortium of universities and research institutes in South Africa investigating the biological control of invasive alien weeds and several crops pests. Martin has served as the President of the Entomological Society of southern Africa, Secretary General of the Afro Tropical Sub Region of the International Organisation for Biological Control and is currently the President of the International Organization for Biological Control.

Classical biological control in Africa: constraints and opportunities

Martin Hill[1]

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The Convention on Biological Diversity (CBD) and the Nagoya Protocol (NP) establish the international legal framework for access and benefit sharing (ABS). The NP was initiated in October 2014 and has been ratified by many countries active in classical weed biological control. Whilst understanding the need for access and benefit sharing of biodiversity, the Nagoya Protocol was met with concern by the biological control community as many practitioners were skeptical of how efficiently it might be implemented in signatory states, and feared that it would significantly slow down the process of obtaining the necessary permissions to survey for, collect and export potential biological control agents (Prior Informed Consent (PIC) and Mutually Agreed Terms (MAT)). The International Organization for Biological Control (IOBC) Global established a Commission on Access and Benefit Sharing in 2021 that has resulted in a selection of papers including a special issue of BioControl (2023) that essentially sets out a best practice for implementing the Nagoya Protocol in classical biological control. In kind benefit sharing through support of laboratories, student support, infrastructure sharing of agents has historically been a philosophy of the international weed biological control community. The weed biological control community has prided itself in practicing a public good science. The intentions of the NP are noble as it seeks to reward countries for protecting their biodiversity. However, the unintended consequences of the NP could be that only resource rich countries will be able to afford to practice classical biological control and it will be unaffordable to resource poor counties.

Abstracts
Oral Presentations

Session 1-O1 - Aquatic weed biological control

Stick to your grubs: a flea beetle to combat the seedling recruitment of *Iris pseudacorus* (Iridaceae), an invasive wetland plant in the Southern Hemisphere

Gianmarco Minuti[1,2], *Paula Gervazoni*[3,4], *Rosa Nicoló*[1], *Olga Delange*[1], *Marco Cantarelli*[1], *Erin Boon*[2], *Celeste Franceschini*[3], *Alejandro Sosa*[5], *Iris Stiers*[1,6] & *Julie Coetzee*[2]

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The European macrophyte *Iris pseudacorus* L. (Iridaceae) has invaded temperate wetlands around the world and is considered a suitable target for biological control, especially across the Southern Hemisphere. The principal candidate biocontrol agent is *Aphthona nonstriata* Goeze (Coleoptera: Chrysomelidae), a flea beetle that damages the foliar tissue of the plant in its adult stage, and feeds on the rhizomatic structures as a larva. Studies across the invaded range of the plant have highlighted high levels of genetic differentiation among populations, suggesting sexual reproduction as its main mean of dispersal. This, coupled with the challenges posed by climate change on weed biocontrol, calls in question the ability of *A. nonstriata* to control the recruitment and spread of its target. Accordingly, the objectives of the current study were twofold. First, to compare the germination and early growth of *I. pseudacorus* seeds between its native European and invaded South American range, using the absence of cold stratification as a proxy of climate change. Secondly, to evaluate the ability of *A. nonstriata* to stunt the growth of different plant stages of *I. pseudacorus,* including seedlings. Our results confirmed a 20–30% higher germination rate in Argentinian seeds compared to seeds from the native range in Belgium. Furthermore, seeds from Argentina performed significantly better – in terms of germination and early growth – in the absence of cold-stratification, suggesting an adaptation to warmer winter temperatures. Finally, our impact assessment showed that *A. nonstriata* is able to stunt the growth of *I. pseudacorus* even at low insect densities. As expected, impact to juvenile plants was significantly higher, with under 10% survival rate after a period of 6 weeks. These results add to the current knowledge on the invasion biology of *I. pseudacorus* and support the prioritization of *A. nonstriata* as the main candidate biocontrol agent for this weed in the Southern Hemisphere.

Session 1-O2 - Aquatic weed biological control

Lessons on recovery: contrasting the impact of biological control of giant salvinia (*Salvinia molesta*) in tropical and subtropical regions

Rodrigo Diaz[1], Victoria Ayala[1], Dane Shackelford[1], Charles Wahl[4], Steven Woodley[2] & Jorge Ortiz[3]

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The rate of recovery of ecosystem services following biological control is rarely measured. By measuring water quality parameters during the biological control of giant salvinia (*Salvinia molesta*) in Puerto Rico and Louisiana, we were able to learn from programs in tropical and subtropical regions. The objectives of this presentation are to describe the implementation of the biological control program and monitoring of services and highlight the challenges and opportunities for salvinia management. Sampling consisted of measuring water temperature, dissolved oxygen, giant salvinia and SAV cover, and weevil densities. Results demonstrated that in Puerto Rico biological control led to a fast reduction of salvinia coverage, following by a recovery of dissolved oxygen levels. This recovery has been stable for at least two years suggesting a potential long-term impact. In contrast, biological control in southern Louisiana presents an annual cycle with rapid reduction in salvinia coverage in late summer and fall, followed by increases in the spring. Consequently, dissolved oxygen and presence of SAV cover fluctuated based on salvinia coverage. The implications of this short-term recovery of services in subtropical wetlands are unknown and deserve further investigation. The implementation of augmentation biological control early in the season will be discussed as a more aggressive approach for salvinia management in subtropical regions.

Session 1-O3 - Aquatic weed biological control

South Africa vs. south Florida: mass rearing and inundative releases of *Megamelus scutellaris* to manage waterhyacinth (*Pontederia crassipes*)

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Waterhyacinth is one of the world's worst aquatic weeds, originates from South America, and is a problematic invasive species in south Florida. Herbicides such as 2,4-D amine, diquat, and penoxsulam are used extensively to manage waterhyacinth populations in Florida. Since the 1970s, several biological control agents have also been released, including *Neochetina eichhorniae* Warner (Coleoptera: Curculionidae), *Neochetina bruchi* Hustache (Coleoptera: Curculionidae), *Niphograpta albiguttalis* Warren (Lepidoptera: Crambidae), and the most recent, *Megamelus scutellaris* Berg (Hemiptera: Delphacidae). Although *M. scutellaris* has established in south Florida and California, it does not reach high abundances and is not easily recovered in the field. In South Africa, promising results have been achieved using inundative releases of *M. scutellaris* to effectively manage waterhyacinth populations. However, the populations used in South Africa were sourced from Buenos Aires, Argentina rather than the Uruguay populations released in Florida, so differences in efficacy between these populations could exist. Through collaboration with South African researchers and Florida Fish and Wildlife Conservation Commission, we will mass rear both the Uruguayan and Argentinian *M. scutellaris* and conduct inundative releases to determine whether the release methods used in South Africa can be used to manage waterhyacinth in south Florida. Efficacy of the two source populations of *M. scutellaris* will be compared. Inundative releases will occur at selected sites in Florida, and waterhyacinth surface coverage, plant size, and health, as well as insect abundances will be compared. Determining the efficacy of inundative releases of these different populations will improve efforts to control waterhyacinth and better our understanding of *M. scutellaris* as a biocontrol agent.

Session 1-O4 - Aquatic weed biological control

BioControl meets AI: implementation of real-time satellite monitoring for detection and management of giant salvinia (*Salvinia molesta*)

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Giant salvinia (*Salvinia molesta*) is considered as one of the most problematic aquatic weeds worldwide. While biological control with the salvinia weevil (*Cyrtobagous salviniae*) has proven to be self-sustaining in tropical regions, its impact in subtropical and temperate regions is less reliable. To improve the biological control program, early season salvinia detection and targeted weevil releases are needed. Since remote sensing is an inexpensive and fast monitoring strategy, this project leverages cloud computing and satellite datasets from the Sentinel-2 satellite to establish a real-time and publicly accessible monitoring tool. Real-time satellite imagery can be used to monitor weevil damage by quantifying the change in surface coverage and health condition of salvinia mats. Using the Sentinel-1 satellite dataset and Google Earth Engine (GEE) platform, the dominant macrophyte species are classified with a machine learning algorithm and mapped across time. This produces a time-series that measures the spatial-temporal changes of salvinia coverage. In this study, we present results of the implementation of this satellite monitoring on the biological control program of salvinia in Lake Ossa, Cameroon. Our results showed that upon the release of the weevil in 2019 the salvinia coverage decreased 70% as of December 2023. Based on the latest satellite images (January 2024), isolated salvinia mats are in the upper arms of the lake. The generated outputs can be used by stakeholders to optimize management efforts since spatial information is available. The application of satellite imagery for monitoring other biological control projects will be discussed.

Session 2-O1 - Biological control and the agroecology toolkit

Unveiling the architecture of biological control

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On at least 12% of today's farmland, biodiversity loss, chemical pollution and land use change have caused a critical loss of ecological functioning - directly jeopardizing sustainable food production. To reconstitute those foundational ecosystem services, interdisciplinary science and systems thinking is crucial, while tactical links need to be built to emerging fields such as agroecology. In such endeavors, one can only put biodiversity into practice by accounting for the intricate ecological interplay between plant and animal biota over space and time. Indeed, the architecture of inter-organismal interactions or 'biostructure' is what ensures proper ecosystem functioning. In this presentation, we build upon two case studies to illuminate i) the pivotal role of biostructure in biological control, and ii) the extent to which it has been historically overlooked. First, we uncover how multiple natural enemies forage on nectary-bearing legumes, but the portrayal of those interaction linkages is profoundly incomplete and their ensuing implications for biological control under-investigated. Legumes are rapidly becoming premier levers in the global transformation of food systems, but whether and how they feature in pest control equations is shrouded in mystery. Second, we visualize the extent to which single natural enemy species routinely affect multiple crop pests – thus providing valuable services at a landscape scale. Yet, as crop- and pest-centric attitudes prevail in pest management science, such 'area-wide' service delivery goes totally unnoticed. We argue that ample benefits can be reaped by consciously looking beyond the confines of biological control science and by pursuing linkages to conservation agriculture or landscape ecology. Overall, we hope that our presentation will drive a new wave of biodiversity & ecosystem function research and advance truly integrative forms of biological control. It could very well alter the course of global agriculture.

Session 2-O2 - Biological control and the agroecology toolkit

Conservation biological control in tropical agroecological farms: the role of landscape and local features

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Brazil is one of the largest agricultural producers in the world but also a megadiverse tropical country. Therefore, there is a fruitful ground to develop conservation biological control strategies based on agroecological practices to conciliate biodiversity conservation and farming productivity. Such a big task demands understanding how local and landscape features interact in moderating the effects of natural enemy biodiversity on pest populations. We aimed to provide evidence on how local management and landscape features affect natural enemy populations and their biological control services in tropical farms using agroecological practices. We sampled distinct groups of natural enemies of selected pests and measured biological control services in a series of studies in small farms cropping organic vegetables in the Brazilian Federal District. Natural vegetation areas in the landscape consistently benefited the species richness of predatory ants (2015, 18 farms), whitefly natural enemies (2019–2021, 20 farms), aphid parasitoids (2022–2023, 25 farms), but not predatory coccinellid species richness (2021–2023, 25 farms). The scale of response to landscape features varied between groups. For predatory ants and whitefly natural enemies, local agroecological practices like less intensive management, crop diversification, and agroforestry system stripes favored their abundance. For aphid parasitoids and predatory coccinellids, local non-crop plant stripes mediated the coexistence and abundance of species. There was a positive relationship between natural enemy biodiversity and biological control in all study systems, suggesting that complementary effects may arise, mostly in intermediate levels of diversity. Therefore, the natural vegetation in the landscape acted as reservoirs of natural enemy species, while agroecological practices increased habitat permeability and favored pest regulation by natural enemies in the tropical organic farms we studied.

Session 2-O3 - Biological control and the agroecology toolkit

Resolving effects of hedging practices on biocontrol communities and trophic interactions

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Perennial treenut agroecosystems require canopy maintenance to control growth and size which has implications canopy architecture effects on arthropod communities. Natural enemies of pests often have micro-climate preferences, and changes in plant architecture may alter the distribution of natural enemies and the corresponding effects on pests. Here we share current research within pecan systems on the effects of hedge pruning on pests and natural enemies. We monitored pest populations and associated injury, natural enemy counts, and parasitism rates estimated from molecular analysis of aphid mummies. Combined, the effects of hedge pruning mature pecan trees had a mixture of negative, positive and neutral effects on arthropod communities. A key parasitoid was revealed during studies, *Aphelinus perpallidus* (Gahan) (Hymenoptera: Aphelinidae), with a complexity of interactions present with hyperparasitoids. Further analysis of predator communities is needed and on-going. Given the quite complex impacts of hedging that alter habitat heterogeneity that arthropods are exposed to, pruning clearly has implications for pest management and the functioning of biological control communities.

Session 2-O4 - Biological control and the agroecology toolkit

Combining an entomopathogenic fungus with crop diversification boosts its control efficacy against an important soil-dwelling pest

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Crop diversification through the implementation of trap crops, reduces damage of belowground pest insects by distracting them from the main crop. Unfortunately, this reduction is generally not satisfactory for farmers, and does not reduce pest densities. To kill soil-borne invertebrate pests, entomopathogenic fungi (EPF) such as *Metarhizium brunneum* are promising biocontrol agents, but their efficacy in the field is so far often insufficient. In field and greenhouse experiments we tested a combined application of EPF and trap crops mixtures for the control of wireworms, the larvae of click beetles (Coleoptera: Elateridae), a mayor soil-dwelling insect pest worldwide. We investigated the effect of a combined application on the distraction of wireworms from the main crop, the wireworm population, the damage caused by wireworms in potatoes and maize, and the establishment of *M. brunneum* spores in the soil. To identify attractive trap crops, larvae from field experiments were collected for molecular gut-content-analysis, and the rhizosphere competence of *M. brunneum* with trap crops was evaluated in a greenhouse experiment. Trap crops successfully lured wireworms away from maize, but not from potatoes. However, wireworm abundance and damage were reduced in potatoes by a combined application of EPF and trap crops by 50.8% and 42.5%, respectively. Trap crop strips maintained a higher *M. brunneum* spore concentration after application compared to bare soil. Greenhouse experiments showed distinct rhizosphere competence abilities of certain plant species with wheat, buckwheat and ryegrass as best candidates for endophytic colonization. Crop diversification combined with EPF application poses to be an efficient and agroecologically sound measure for the control of belowground insect pests in arable crops. Depending on the trap crops used, it may provide additional benefits on top of the biocontrol effect, e.g. increase in-field biodiversity, or facilitate nitrogen fixation.

Session 2-O5 - Biological control and the agroecology toolkit

Stabilizing the agri-food web: the case for apex arthropod predators in the greenhouse

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In natural ecosystems, apex predators play a key function in stabilizing trophic food webs by mitigating population growth of both R-selective pest species and intermediary predators and parasitoids. Yet for decades, pest management programs in greenhouse agroecosystems have typically relied most heavily on inundative releases of specialist natural enemies (both parasitoids and predators), but whose limitations in consistent and adaptable pest control include the size, aggressivity, identity and mobility of pest prey or the physicochemical characteristics of host crops. In recent times, more research has arisen that supports the value of omnivorous predators, especially as applied through open rearing systems. This talk will summarize some of the research recently conducted in Canada to identify and characterize the biocontrol potential of native generalist hemipteran predators and to develop best practices for their introduction to commercial greenhouse agroecosystems through open rearing systems.

Session 2-O6 - Biological control and the agroecology toolkit

Recruiting biocontrol agents to high tunnel tomato: companion plants vs. weeds

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High tunnels offer an ideal growing condition for tomato production in the midwestern United States. However, some pests (especially spider mites, aphids, and thrips) also benefit from these conditions and often require management intervention. Pest management by resident or released natural enemies can be effective against these pests, but recruiting and retaining them in high tunnels can be challenging. This project determined if interplanting tomato with weeds can be effective in retaining resident and commercially released natural enemies compared to the traditionally used companion plants dill, basil, marigold, and sweet alyssum. We found that overall insect counts were higher on tomato with companion plants compared to the control and weedy tunnels. Aphids were the most dominant pests identified on tomato followed by thrips, and overall pest counts did not vary among tunnel types. Predator counts were highest on tomato intercropped with companion plants and weeds, especially when biocontrol agents were released. Among the companion plants, the majority of released biocontrol agents were recovered from sweet alyssum (79% of *Hippodamia convergens* and 46% of *Orius insidiosus*). No difference in parasitoid counts were observed among tunnel treatments. Common weeds observed in interplanting zones were *Echinochloa* spp., *Digitaria sanguinalis*, and *Ipomoea aquatica*. Among all weeds, the highest natural enemy to pest ratio was observed for *Setaria viridis*, *Lepidium virginicum*, *Oxalis stricta*, and *Plantago lanceolata* where equal to or more natural enemies were observed compared to pests. These results indicate that diversifying high tunnels with companion plants or controlled weeds could contribute towards successful augmentative and conservation biocontrol programs.

Session 2-O7 - Biological control and the agroecology toolkit

Promoting a preventive lens for biological control in agroecosystems

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In recent decades, agroecological practices have been recognized as effective for food production and environmental stewardship. Unfortunately for pest management, many of the practices promoted as agroecological have increasingly focused on a reactive approach. However, first-hand experience from smallholder farmers around the world has shown that a preventative approach effectively increases biological control agents. Here, I will discuss from an ecological and social perspective, and from my empirical experience working with farmers in Guatemala and Mexico, the problems with some of the curative pest management practices promoted as agroecological, and the benefits of practices that enhance the activity of biological control agents with a preventive approach. A paradigm shift is urgently needed to help halt or reverse the biodiversity crisis, and to become a core component of initiatives pursuing agroecological transitions.

Session 2-O8 - Biological control and the agroecology toolkit

Maize direct response to entomopathogenic nematodes

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Interactions across multiple trophic levels, which include plants, herbivores, and herbivore natural enemies, play a crucial role in shaping ecosystem functionality and biodiversity. Despite extensive research on these interactions, it remains uncertain whether plants can directly perceive and react to herbivore enemies. In this study, we investigated how maize plants react, both locally and systemically, to the presence of entomopathogenic nematodes (EPNs) in the soil. EPNs are used in biological control to manage various insect pests, including the western corn rootworm (WCR), one of the main pests affecting maize production. By integrating metabolomics and transcriptomics analyses, we found that maize plants respond to EPNs, leading to alterations in the primary metabolism within leaves and roots. Notably, the profiles of soluble sugars exhibited changes in plants exposed to EPNs. Our findings underscore the importance of understanding these complex interactions in the development of effective and environmentally friendly pest management strategies.

Session 2-O9 - Biological control and the agroecology toolkit

Incentivizing biocontrol use in agroecological systems by extending the benefits beyond pest control

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Biological control by predators or parasitoids is undoubtedly a beneficial tool in agroecology. In this context, biological control can be implemented either by artificial augmentation or conservation. Despite several benefits from both and the potential for their integration, conservation biological control is expected to be more compatible with the agroecology theory as it makes more use of nature in open fields. Nonetheless, implementing conservation biological control in the field has been a challenge for reasons such as: (i) farmers usually are afraid of losing farming area by allotting space for conservation features, (ii) sometimes the results are context-dependent, making it hard to have solid predictions, (iii) the requirement of preventative efforts to implement it, and (iv) there is still a lack of solid economics on the implementation of conservation biological control and the ensuing profitability. A potential way of incentivizing the implementation of conservation biological control is by extending its benefits. In that sense, we have been investigating conservation biological control in some agricultural settings in a manner that it could provide benefits beyond pest control. For example, the construction of terrace embankments on field slopes is essential to mitigate soil erosion; and additionally, we found out that spontaneous vegetation occurring atop the terraces mediates an increase in biocontrol of maize pests. Moreover, in some intercropping systems we found out that some companion plants can shelter key natural enemies to promote biocontrol, and at the same time be harvested for the market or serve as food for cattle. Lastly, augmentative biological control could also be further incentivized in agroecology by its integration with conservation biological control. All in all, because conservation biological control is not a 'tit for tat' strategy we need further studies to improve its efficacy and adoption in agriculture.

Session 3-O1 - Applied biological control in Latin America

99.9% of the more than 1000 species of natural enemies used in biocontrol in Latin America are safe

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How many species of natural enemies used for biological pest control in Latin America were beneficial or caused negative effects? To answer this question, we listed all natural enemies found in the book *Biological Control in Latin America and the Caribbean,* 2020, CABI, ISBN-13: 9781789242430. The more than 1000 species found were ranked by: (i) being exotic or endemic, (ii) providing pest reduction or not and (iii) producing negative side effects or not. None of the endemic species caused negative effects, whereas release of one exotic species in several Latin American countries did result in control of the pest and may have resulted in negative side effects in some of the countries where released. Overall, this is a very satisfying result in a region with the largest area of crops under biological – almost 100 million hectares - worldwide. Part of the explanation of the extremely low incidence of problems might be the application of environmental risk analyses since the 1980s.

Session 3-O2 - Applied biological control in Latin America

Advances in the application of biological control in Brazil: challenges and opportunities

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Although Augmentative Biological Control programs in Brazil began in the late 1960s, it was with graduate courses in entomology that biological control gained strength. The Entomological Society of Brazil was created in 1972 and many entomologists have specialized in biological control abroad. However, the milestone for large-scale use in Brazil was the registration of *Helicoverpa armigera* in 2013. This pest, which has more than 150 hosts, occurred at a time when there were no chemical products registered for its control. Therefore, we used the virus and *Trichogramma pretiosum* to control it, with enormous success. Problems that hinder the progress of biological control were then demystified, as the farmer's acceptance of this type of control, which is not so easy to use; the cost of the biological product not being so important due to its ecological and social advantages; and that the specificity of the biological agent is irrelevant if we consider that the current philosophy is Integrated Pest Management (IPM) toward sustainable agriculture. Thus, currently, 25 million hectares are treated with bioinputs, with an emphasis on microorganisms alongside macroorganisms and semiochemicals. There are more than 600 registered products and almost 200 companies selling bioinputs. Although less used than microorganisms, macroorganisms are already used on millions of hectares in sugarcane, mainly, with great possibilities in other crops, such as soybean, corn, cotton, tomato, fruit trees, coffee, among others. Some obstacles must still be overcome in order to Brazil maintain world leadership in the use of bioinputs, including storage and transport logistics, legislation, mass production of macroorganisms using automation and greater public awareness on the subject. Nevertheless, one of these obstacles has already been overcome, that is, the release of natural enemies using drones, carried out on millions of hectares in the country.

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Session 3-O3 - Applied biological control in Latin America

Classical biological control for *Hypothenemus hampei* (Coleoptera: Curculionidae) in Colombia using African parasitoids

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Coffee Berry Borer (CBB) is the most important pest of coffee crops, limiting production and quality of the drink. Since its arrival to Colombia in 1988, Cenicafé, the Coffee Research branch for the Colombian Coffee Growers Federation, began to develop an integrated pest management strategy focusing on cultural and biological control strategies. First, three African parasitoids species were introduced: *Cephalonomia stephanoderis*, *Phymastichus coffea* and *Prorops nasuta*; however, only the latter was successfully stablished in Colombian coffee crops. More recently, based on these introductions, a new approach to control CBB using *P. coffea* and *P. nasuta* in an Area-Wide strategy was tested. The African parasitoids were mass reared using artificial diets, then field-released in CBB infested coffee plots in Chinchiná, Colombia. For this, more than 1.5 million wasps of each species were released on a 61-hectare coffee farm in replicated plots, resulting in parasitism rates of up to 7.7% for *P. nasuta* and 56.3% for *P. coffea*. This led to a maximum reduction in *H. hampei* field populations of 81% from dispersal coffee plots and 64.3% in colonization coffee plots. On the other hand, reference genomes of 295 Mega bases (Mb) were generated for *P. nasuta* and 421 Mb for *P. coffea*, corresponding to 99% and 98% genome completeness, respectively. 17,631 and 20,147 putative genes were identified for each of the species. Estimates of genetic variability in laboratory populations of these wasps showed relatively low levels of nucleotide diversity and genetic diversity in both species. Reintroductions of parasitoids from Kenya are expected to increase genetic vigor and maximize their potential as natural controllers of CBB.

Session 3-O4 - Applied biological control in Latin America

Meta-analysis on the consistency in the control efficacy of *Bacillus* spp formulation against *Alternaria alternata* in tomato: results from Chile, Peru, Argentina, Brazil and Mexico

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One of the main limitations in the use of biological control is a perception of inconsistency in results. This study aims to establish, through a meta-analysis, the level of consistency in control levels of a commercial formulation of *Bacillus* spp. (Nacillus Pro®, Bionativa Chile) against *Alternaria alternata* in tomato crop. The trials were conducted in Chile, Peru, Argentina, Brazil, and Mexico, all using the same dose-response curve. Data on percentage control were standardized both against the control and registered commercial references, disease severity levels before and after applications. Geographic location, climatic conditions, and genetic material used were also considered. A multivariate analysis was conducted to establish principal components. The results indicate high consistency in control levels, with eigenvalues >1 for treatments, doses, and damage levels of the control. The variation in efficacy levels between different trials for the biological product did not differ from those obtained with chemical references (P = 0.361). In conclusion, there is no evidence a significative variability in the control efficacy of *Bacillus* spp. formulation under study compared to chemical references. These variations are primarily related to environmental conditions and the farmer´s lack of discrimination between different biological products.

Session 3-O5 - Applied biological control in Latin America

Biological control programmes in Argentina: an overview

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Argentina has a long tradition in applied biological control. Since the early 1900s, several natural enemies, mainly parasitoids, were introduced denoting a marked reliance on classical biological control. However, since the 2000s conservation biological control started to gain attention. In addition, the biocontrol of weeds has a great development, and this country is pioneering the use of entomopathogenic nematodes for pest control. Nowadays, classical biocontrol is applied on a few aquatic and pasture weeds, and for insect pests of fruit and timber trees. Also, a small fraction of vegetables production is under augmentative biocontrol. Unfortunately, records of the action of those natural enemies are not always kept, and their impact may not be easy to evaluate. Argentina has a public free-access platform with information on pests of interest for the main crops (Argentine National Pest Surveillance and Monitoring System, SINAVIMO), responding to national and international phytosanitary surveillance needs; however data related to the natural enemies associated to those pests and other knowledge of interest for biological control implementation is incomplete or scattered, and hard to come by. Since the last decade, efforts are being made to enhance interactions among academic institutions, agribusiness, extension services and farmers to implement biological control although much work is needed to transfer this biotechnology to the field. Besides, evaluation of native species as biocontrol agents and the development of protocols for their mass production should be prioritized to boost biological control in this country. We highlight the growing interest in biocontrol techniques, from public and private sectors that reflects in funds contributing to the development of a biotechnological leap. Augmentative biocontrol, although involving the need of inputs, represents an important tool in the transition to agroecological production systems.

Session 3-O6 - Applied biological control in Latin America

Parasitoids at work! An applied 6-years account of the use of *Spalangia endius* for the control of *Stomoxys calcitrans* in coffee wastewater management

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Coffee stands as one of the most important crops in Costa Rica. High national consumption and highly profitable international trade make this industry a driving force in the national economy. Consequently, the enormous quantities of organic materials processed can give rise to serious environmental issues. One of these challenges pertains to how to manage the wastewater produced during pulp separation. In some large coffee processing plants, the effluents of wastewater are discharged into dedicated grasslands. However, this methodology has presented a challenge as well: sugary wastewater applied over grasslands has become a perfect spot for the stable fly, *Stomoxys calcitrans*, to thrive and then move on to the cattle, animals, and humans in surrounding towns. This study documents the 6-year-long effort to control and manage this pest under such a scenario through the use of an Integrated Pest Management (IPM) approach based mainly on the inundative biological control technique, in addition to cultural, ethological, and chemical measures. The biological control agent used corresponds to *Spalangia endius* and has been released every season at 2–3 week intervals. The types and frequencies of chemical pesticides decreased every year, reaching up to a 100% decrease. A grand total of 11,685,000 parasitoid wasps have been released so far. Socio-cultural and technical aspects and consequences of the implementation of IPM measures will be discussed.

Session 3-O7 - Applied biological control in Latin America

First record of *Anagyrus tristis* (Hymenoptera: Encyrtidae) in Mexico and its potential for biological control of *Phenacoccus madeirensis* (Hemiptera: Pseudococcidae)

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Anagyrus tristis is a gregarious parasitoid that had only been associated with the genus *Rastrococcus* (Pseudococcidae) in Indonesia, but it was recently found parasitizing *Phenacoccus madeirensis*, an economically important pest of peppers in protected agriculture in Mexico. The aim of this study was to report the presence of *A. tristis* in Mexico and to determine its biology on *P. madeirensis*. Here we have determined its developmental time on two developmental stages of *P. madeirensis*: (i) adult females and (ii) third-instar nymphs. The assays were carried out under laboratory conditions: 25 ± 2°C, 75 ± 5% RH and 12:12 h L:O. *A. tristis* developed well on adult females or third-instar nymphs of *P. madeirensis,* but a difference was recorded in parasitoid emergence, 92.0 vs 86.4% when they developed in adult females and third instar nymphs, respectively. The incubation period was not different in both developmental stages (55.1 ± 2.3 to 58.5 ± 0.8 h). The larval developmental time was different in adult females (3.7 ± 0.2 days) when compared to third-instar nymphs (4.1 ± 0.1 days), but the pupal period did not differ between stages of host development (10.3 ± 0.7 days). The sex ratio of *A. tristis* was similar in both developmental stages 0.5:1.0 (♂:♀). Parasitoid adults having availability of water or prey, but no carbohydrate source (honey), lived from 2.0 ± 0.1 to 2.7 ± 0.1 days. The survival time with water or host availability, and without a carbohydrate source suggests that there is no host feeding. *A. tristis* female adults having honey availability had similar longevity coming from any stage of host development, 24.7 ± 2.2 and 23.3 ± 2.7 days, respectively. Adult males with honey availability lived 15.9 ± 1.4 and 18.2 ± 2.6 days, respectively. Fecundity of *A. tristis* is being evaluated, and its potential by augmentative biological control against this mealybug in protected agriculture will be assessed.

Session 3-O8 - Applied biological control in Latin America

Risk assessment status of a potential biological control agent of the avian vampire fly in Galapagos

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Island ecosystems can be disproportionately negatively impacted by invasive species. In the Galapagos Islands, Darwin's finches are experiencing drastic population declines due to the invasive avian vampire fly (AVF). This parasitic fly infests bird nests and kills nestlings by overfeeding on their blood. The Enemy Release Hypothesis has been cited as a reason for the uncontrolled spread of AVF as none of the parasitoid wasps that attack AVF in its native range in mainland Ecuador are present in Galapagos. As such, a biological control project is currently underway to address these invasives. Our research focuses on risk assessment of the most abundant of these wasps, *Trichopria* sp., to determine whether it is specific to AVF as a host and what threat it may pose to non-target species in Galapagos if it is selected as a biological control agent. We conducted no-choice experiments in mainland Ecuador to determine the host range of *Trichopria* sp. and discovered that unlike field studies where *Trichopria* sp. primarily emerged from AVF, several semi-closely related species were also attacked. However, further experiments examining host refuge and host location mechanisms including olfactometer trials with nests and nest entities suggest that *Trichopria* sp. could be specialized to foraging only within bird nests and unable to access hosts in alternative habitats, limiting its host range. This work represents early steps towards the selection of a safe biological agent for the conservation of Galapagos avifauna.

Session 3-O9 - Applied biological control in Latin America

Controlling an emerging pest in Mexican horticulture: can we consider *Trissolcus basalis* for controlling the Mexican stink bug *Euschistus rugifer*?

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Most biocontrol agents used for pest management in Mexican horticulture are highly specialized or well selective predators/parasitoids. Thus, non-target pests may gain economic importance and could become more problematic within a bio-based pest management system. Such is the case of the Mexican stinkbug *Euschistus rugifer* which is becoming more frequently encountered in organic sweet pepper production. An egg parasitoid, *Trissolcus basalis*, has been used successfully to control *Nezara viridula* in different countries. Nevertheless, it is still unclear whether this parasitoid may also be effective against the Mexican stinkbug *Euschistus rugifer*. To evaluate if this species could serve as a host for *T. basalis,* laboratory trials were conducted in order to determine the parasitism and hatching rates of the wasp. To evaluate if the crop had an influence over the performance of the wasp 'in planta' trials using sweet pepper and tomato plants were also conducted. Finally, to determine the dose for controlling *E. rugifer*, three doses were evaluated in a semi-field trial: 0.5, 1 and 2 wasps/m^2. Our data suggests that indeed *T. basalis* may also be considered within the IPM of the emergent pest *E. rugifer*. Limitations and considerations are further discussed.

Session 3-O10 - Applied biological control in Latin America

Risk assessment of the parasitoid *Conura annulifera* as a biological control agent of *Philornis downsi* in the Galapagos Islands

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The Galapagos Islands face a significant threat from the invasive avian vampire fly, *Philornis downsi*, which is causing declines in endemic bird populations, including many species of Darwin's finches. Humans introduced this fly unintentionally before the 1960s and it is considered highly invasive in Galapagos. In response to this ecological challenge, the introduction of the parasitoid wasp *Conura annulifera* has been proposed for use in a biological control program against this fly.

This study aims to assess the risks associated with the introduction of *C. annulifera* as a biological control agent in the Galapagos Islands. Through laboratory experiments, we investigated the potential effects on non-target species. The results suggest that this chalcidid wasp exhibits promising biological control capabilities against *P. downsi* while demonstrating minimal risk to endemic species. However, our laboratory experiments showed that a small number of species from related families to *P. downsi*, Sarcophagidae and Muscidae, were parasitized under controlled laboratory conditions, indicating a broader potential host range for *C. annulifera*. Studies assessing the likely physiological and ecological availability of endemic and native species from these families indicate that it would be very unlikely for them to be attacked in the field, however.

This research contributes to the ongoing research on invasive species management and the application of biological control strategies in delicate island ecosystems. By rigorously evaluating the risks and benefits, we aim to provide valuable insights for policymakers and scientists involved in the preservation of biodiversity in the Galapagos Islands.

Session 4-O1 - Free session

Exploring the potential for biological control in industrial hemp crops

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Industrial hemp (*Cannabis sativa* L.) has re-emerged in the United States in the last decade, as a potential crop for its multitude of uses and environmental sustainability due to its low carbon footprint. A critical challenge for growers with hemp cultivation lies in the lack of pest management strategies due to pesticide restrictions in new cropping systems before appropriate testing is complete. Therefore, developing novel strategies, such as biological control, are essential for grower success. Essential to leverage sustainable pest control, this work contributes to the understanding of the prevalent pests that interact with the crop, and the biological control agents that utilize these plants to find prey resources on commonly grown hemp cultivars in the USA Northeast region. In 2022, we conducted visual surveys, to determine the abundance and diversity of important insect species inhabiting fiber/grain and CBD hemp across Pennsylvania. We explored differences in insect community composition between sites and hemp varieties and analyzed potential factors driving pest/natural enemy interactions. Aphids, particularly the cannabis aphid (*Phorodon cannabis*), emerged as predominant pest, constituting 86% of the herbivores feeding on hemp followed by generalist thrip species (*Thrips tabacci*, *Frankliniella* sp., and *Neohydratothrips* sp.) with 3.7%, various chrysomelid species such as flea beetles (genus *Altica* sp. and *Crepidodera* sp.) and cucumber beetles (*Diabrotica undecimpunctata*) with 2.8, and leafhoppers with 1.8%. Among natural enemies, various Coccinellidae species (*Coleomegilla maculata, Propylea quatuordecimpunctata, Harmonia axyridis*) constituted 28%, followed by arachnids with 26%, minute pirate bugs (Anthocoridae) with 15%, ants (Formicidae), hover flies (Syrphidae), lacewings (Chrysopidae), and different families of parasitic wasps were equally represented (~6%). Despite a higher abundance of insect pests for both types of cultivars, this work suggests natural enemy communities are more diverse and evenly distributed than herbivores. These results lay the groundwork for testing appropriate natural enemy-pest pairs for potential in biological control programs.

Session 4-O2 - Free session

Releases of the parasitoid *Pachycrepoideus vindemmiae* for augmentative biological control of spotted wing drosophila, *Drosophila suzukii*

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Spotted wing drosophila, *Drosophila suzukii*, is a major pest of soft-skinned fruit crops in its invaded range in the Americas, Europe and North Africa with little or no parasitism by larval parasitoids. Augmentation of *Pachycrepoideus vindemiae*, a resident pupal parasitoid in North America, may be a sustainable tool for *D. suzukii* management. We tested whether augmentative releases of *P. vindemmiae* could help control *D. suzukii* in caneberry hoop houses in Minnesota, Oregon and California. Results were inconsistent. Most trials showed no detectable post-release effects on parasitism or *D. suzukii* levels, although one trial in Oregon did show elevated parasitism levels in release plots. Larger releases of *P. vindemmiae* may be needed when *D. suzukii* numbers are high, or to overcome the effects of suboptimal conditions and/or dispersal.

Session 4-O3 - Free session

Biological control of whiteflies on protected vegetable crops in Sicily (south Italy): from illusions to reality

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In Sicily about 4,000 ha are planted with vegetables under greenhouses, being the widest Italian area for this production. Tomato is the most important crop, with an almost 200,000-ton production, followed by zucchini, with over 45,000 tons; eggplant and bell pepper, producing almost 40,000 and 27,000 tons respectively, are also important crops. Various pests threaten vegetable production in this area and whiteflies, especially *Bemisia tabaci*, occupy a prominent role, above all for the viruses they transmit. Biological control, although giving valid results against whiteflies, does not establish satisfactorily in this productive area. From a survey conducted within the European project "Virtigation" (https://www.virtigation.eu/), it has been noted how only about 32% of farms use natural enemies (predators or parasitoids) to control whiteflies, regardless of the age and educational attainment of the holder (with almost 45% of the growers who adopt biological control being 40–65 years old and having a low educational level). Predators have the clear prevalence among natural enemies used in Sicily for biological control of whiteflies, especially with *Nesidiocoris tenuis* (used by more than 70% of the farmers adopting augmentative releases of natural enemies), followed by *Macrolophus pygmaeus* (almost 55%) and the phytoseiid mite *Amblyseius swirskii* (less than 30%). Interestingly, predatory Myrid bugs are also used by farms which do not adhere to any organic or integrated production disciplinary. The use of parasitoids is limited, with *Encarsia formosa* used only by little more than 25% of the farmers, and *Eretmocerus eremicus* used by less than 10%. On the basis of this survey, an attempt is made to analyse possible reasons for such a limited diffusion of biological control in a production area of such extent and importance, hypothesizing possible solutions for a promotion of eco-sustainable techniques for pest control in the local protected vegetable crops.

Session 4-O4 - Free session

Pirates to the rescue: expanding the use of *Orius* predators in floriculture

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Orius generalist predators are widely associated with the control of thrips, spontaneously colonizing field crops, and released in augmentative biocontrol programs. Commercialized species are anthophilous and very effective against flower pests such as *Frankliniella occidentalis*, however, their impact on foliar pests is limited. Furthermore, the uptake of *Orius* predators has been limited in ornamentals, as these predators do not establish satisfactorily. In recent years, our group evaluated alternative species and strategies, to improve the establishment of *Orius* in ornamental crops and extend their target pest range.
In chrysanthemum, we found that *Orius* species reduce the densities of leafminers, and work additively with the parasitoid *Diglyphus isaeae.* In another experiment, *O. laevigatus* controlled a dual infestation of both *F. occidentalis* and *Aphis gossypii*. In this system, the addition of predatory mites was redundant, and could even be detrimental as it competed with *O. laevigatus* for the shared food sources. Finally, providing supplemental food on young plants attracted the adults to the young crop and away from the soon-to-be harvested plants, enabling the maintenance of the population.
In gerbera, we found better control of foliar pests (*Echinothrips americanus, Chrysodeixis chalcites*, and *Trialeurodes vaporariorum*) with *O. majusculus* and *O. minutus*. In contrast, control of *F. occidentalis* was better with *O. laevigatus*. *Orius* species preferred different plant parts for foraging and oviposition, and combinations of species complemented each other on plants infested with pests attacking distinct plant parts. Under winter conditions, gerbera whitefly control was enhanced when the normal photoperiod of 11.5 hours was extended with low intensity of blue LED light, for both the diapause-sensitive *O. majusculus*, as well as for the non-diapausing *O. laevigatus*.

Session 4-O5 - Free session

When competitors join forces: using consortia of entomopathogenic *Pseudomonas* bacteria, nematodes and fungi for pest control

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Below-ground pests are difficult to control because either no effective control methods exist or suitable insecticides are or will soon be banned due to their negative effects on the environment. We evaluated the potential of disease-suppressing *Pseudomonas chlororaphis* bacteria with entomopathogenic activity for insect control. Moreover, we combined the pseudomonads with entomopathogenic nematodes (*Steinernema feltiae*) and fungi (*Metarhizium brunneum*) with the aim to increase reliability and efficacy of biocontrol measures.

In a series of experiments ranging from the greenhouse to the field, *P. chlororaphis* emerged to be highly efficient in controlling the cabbage maggot *Delia radicum*, an important pest of Brassicacean crops. Furthermore, the triple consortium of *P. chlororaphis* with *S. feltiae* and *M. brunneum* increased the number of marketable radishes by 50% in a field trial. In several experiments, we observed increased pest control when combining the pseudomonads with the nematodes or the fungi. These synergistic effects were verified when applying the combinations against two further pests. The triple consortium was the most lethal and fastest killing treatment against *Pieris brassicae* and *Diabrotica balteata* larvae. In the early stages of the infection, all three agents established inside the larvae.

Our results show that entomopathogenic pseudomonads, nematodes and fungi are compatible and could potentially be used to control a variety of below-ground insect pests.

Session 4-O6 - Free session

Biocontrol sweet spot: stepwise screening toward the identification of bacteria protecting strawberries from *Phytophthora cactorum* root and crown rot

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Phytophthora cactorum is a soilborne pathogen widespread in all continents, highly problematic in horticulture: (i) it is hard to contain, as motile zoospores swim far and fast, (ii) it is hard to eradicate, as dormant oospores survive in the soil and cause infection for years, and (iii) it has a very broad host spectrum and affect more than 200 plant species, among which many economically relevant crops. In strawberry cultivation in particular, *P. cactorum* decreases the yield by up to 30% both pre- and post-harvest: it causes root, crown, and leather rot, eventually stunting the whole plant. Management is challenging, as *P. cactorum* develops resistance to oomycides, and many chemicals are being phased out for their detrimental effects on human health and the environment. By bypassing these pitfalls, biological control is envisaged by policymakers and researchers as an ideal alternative, but few biocontrol-based alternatives are available on the market to date.

For this sake, we performed a comprehensive and stepwise screening to identify biocontrol organisms (BCOs) for the *P. cactorum* – strawberry pathosystem. A collection of 300 bacteria, mostly *Pseudomonas* and *Bacillus* spp., was screened for their antagonistic activity in an innovative high-throughput *in vitro* assay. By using spores as a pathogen inoculum instead of mycelium for confrontation assays, we were able to study both mycelium and spore inhibition at once. Candidates with strong *in vitro* activity were characterized for the production of lytic enzymes, bioactive supernatants and volatiles, as well as their activity against other phytopathogens. The antagonism of the top performers was assessed *in planta*, in detached leaf bioassays and greenhouse trials. We identified several candidate BCOs with antagonistic activity both *in vitro* and *in planta*. In an effort to decipher the underlying mode of action, we sequenced, assembled, and annotated their genomes to identify biosynthetic gene clusters.

Session 4-O7 - Free session

Insecticidal pseudomonads – interspecies interactions and adaptation to insect larvae

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Insecticidal pseudomonads are promising candidates for the biological control of plant diseases and insect pests due to their antifungal and insecticidal activities. Although many traits enabling root colonization and insect pathogenicity are already known, it is not clearly understood how these bacteria interact with other entomopathogens and how they are adapted to a life in insects. We investigated the interaction of *Pseudomonas protegens* CHA0 with the entomopathogenic nematode *Steinernema feltiae* RS5 as well as the nematode mutualistic bacteria *Xenorhabdus bovienii* SM5. CHA0 inhibited SM5 *in vitro* whereas the two bacteria coexisted upon hemolymph-injection in insect larvae. Force-feeding CHA0 to the larvae followed by infection with RS5, did not alter bacterial coexistence nor did the presence of CHA0 affect nematode reproductive success or progeny virulence. CHA0 might be an opportunistic pathogen as it benefited from RS5 probably by exploiting access routes formed by the nematodes penetrating the larval gut epithelium. To further investigate the relationship of pseudomonads with insects, we performed a serial passaging experiment with *P. protegens* CHA0 based on serial infection cycles of insect larvae. Although a few populations displayed an altered insect killing speed after multiple infection cycles compared to the original strain, bacterial virulence did in general not substantially change. Only a few mutations emerged, some of them connected to the bacterial membrane structure. Our results suggest that insecticidal pseudomonads can be combined with entomopathogenic nematodes for biological control and that the insecticidal trait of pseudomonads is stably maintained.

Session 4-O8 - Free session

Side effects of cyantraniliprole and neem-based insecticides on *Myzus persicae* biocontrol agents

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In 2021, a new strain of the aphid *Myzus persicae* was found in sweet pepper greenhouses in the Netherlands. This new strain is resistant to flonicamid and has a higher reproductive rate than the flonicamid-susceptible strain of *M. persicae*. Growers are currently relying on cyantraniliprole and neem-based insecticides for the chemical control of this strain in greenhouses, but knowledge regarding their side effects on biocontrol agents of *M. persicae* is missing. An experiment was set up to investigate the side effects of these insecticides on two common biocontrol agents of *Myzus persicae:* the predator *Propylea quatuordecimpunctata* and the parasitoid *Aphidius matricariae*.
The experiment was conducted in greenhouses on bell pepper plants. Plants infested with the flonicamid-resistant strain of *M. persicae* were treated with one of the two insecticides and one of the two BCAs. Aphid infested untreated plants acted as control. Two weeks later, plants were checked for the number of aphids, *P. quatuordecimpunctata* larvae and for *A. matricariae* mummies were collected and the number of hatched and unhatched mummies was assessed 3 weeks later. Unhatched mummies were dissected, assessing the number of parasitoid larvae and unemerged adults. The results showed a negative effect of the neem-based product on the development of *A. matricariae* parasitoids by increasing the number of unhatched mummies. On the predator *P. quatuordecimpunctata,* both insecticides reduced the amount of food resource available (aphids) to the point that it negatively affected the reproduction of the biocontrol agent.

Session 4-O9 - Free session

Plant guttation a potential nutrient-rich food source for insects in peach

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Plant guttation, the exudation of fluids from the xylem and phloem sap at leaf margins, is prevalent in annual and perennial crops. Its composition encompasses organic compounds like carbohydrates, proteins, enzymes, and amino acids, as well as inorganic compounds such as salts and ions. Recent research has demonstrated the effect of plant guttation on the diversity and fitness of natural enemies in the highbush blueberry system. In the present study, we hypothesized that guttation fluids produced by peaches (*Prunus persica*; Rosaceae) provide a suitable food source for the fitness of insect pests and natural enemies in this system. To test this hypothesis, we determined the effects of plant guttation on the fitness parameters (longevity and egg load) of a frugivorous pest, as well as of two natural enemies present in peach. Newly emerged adults were fed daily on different plant-derived food sources from peach: (i) plant guttation, (ii) extrafloral nectar, (iii) aphid honeydew, (iv) sugar + protein solution (as positive control), and (v) water (as negative control) under controlled laboratory conditions. Insect fitness was measured for all species and compared among treatments. These results will be discussed with the composition of the plant guttation fluid compared with the other plant-derived food sources present in the crop. This study documents the potential positive effects of plant guttation on an arthropod community in an agroecosystem for the first time. The ongoing study has received financial support from grant PID2022-139988OB-I00 funded by MCIN/AEI/ 10.13039/50110 0011033 and FSE+.

Session 4-O10 - Free session

Conservation biological control under threat on the High Plains

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The High Plains of the USA is characterized by intensive production of cereals, oilseeds, small grains, and forage crops. Despite seasonal migrations of Lepidoptera and Hemiptera, and periodic pest outbreaks, the majority of pest species are held below economic threshold by a complex of natural enemies that have evolved adaptations to track them across the agricultural landscape, moving among crops to exploit herbivorous prey as they become seasonally available. However, recent trends are threatening the stability of natural biocontrol services in this agroecosystem, most significantly the almost-universal treatment of commercial seed with neonicotinoid insecticides. Besides the myriad environmental impacts of these neurotoxins, their repeated application over vast areas now threatens natural pest control services across the entire region. Not only is the prophylactic use of insecticide anathema to the most basic principles of integrated pest management, but the promotion of seed treatments as a cheap insurance policy fosters a 'zero-tolerance' attitude toward pests in the farming community. I present some selected examples to illustrate the ecological fallacies inherent in this approach. The incessant drive for ever-increasing yields, driven by corporate profits on unsustainable inputs (fertilizers, herbicides, fossil fuels etc.), leads to greater capital investment in each crop cycle, further reducing farmer tolerance for pests, which is a critical prerequisite for preserving natural pest control services. Emergent crops now represent a 'green desert' for predators and parasitoids, even though many pests can be tolerated during vegetative growth stages, and some pest presence is required to recruit natural enemies and support their reproduction. Large agricultural corporations supply both agrochemicals and seed in tandem and have become a consolidated oligopoly with sufficient power to deny farmers access to the untreated seed that many would choose - if they could. An organized political effort is needed on the part of North American producers and consumers to demand regulations, similar to those that have been imposed in the European Union, that will limit the power of the agrochemical corporations to mandate the application of insecticides as seed treatments in industrial scale agriculture.

Session 4-O11 - Free session

Impacts of biostimulant application on the efficacy of parasitoid-based biological control in tomato horticulture

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Microbial biostimulants interact with crop plants to improve plant health, enhance stress resilience, defend against infection and alter plant susceptibility to herbivorous insects. Biostimulants can activate plant signalling and defence pathways, with important consequences for higher trophic levels within the plant-associated ecosystem. In this project we quantified the extent to which parasitoid biocontrol efficacy could be enhanced by altering plant traits through biostimulant application. We work on tomato horticulture: tomato is rapidly emerging as a well characterised model system to investigate biostimulant effects. In northern latitudes tomato crops are grown in glasshouses. One major pest is glasshouse whitefly *Trialeurodes vaporariorum*: it impairs crop yield due to viral disease transmission, extracts of resources from the crop, and promotes mould growth because of honeydew secretion. Management of whitefly by growers relies heavily on the parasitoid wasp *Encarsia formosa*. We studied whether biostimulant application improves tomato plant growth, whether it reduces infestation of plants by whitefly and crucially, whether it influences the ability of *Encarsia formosa* parasitoid wasps to control whitefly on tomato plants. We studied the effect of commercial *Trichoderma*-based biostimulants as well as Chitosan. Our data reveal biostimulant effects on plant growth, fruit yield, and whitefly infestation. This study provides novel insight into the potential for biostimulants to be used alongside biocontrol to manage plant health and protect crop yield.

Session 4-O12 - Free session

A unique combination of prey mites as supplementary food to boost the predators

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The use of supplementary foods to encourage the early establishment and conservation of natural enemies in periods of prey scarcity is a strategy widely implemented in augmentative biocontrol programs. Several commercial factitious foods are introduced into different protected crops. In previous studies, we developed a program to control thrips on chrysanthemums and cucumbers based on the introduction of astigmatids as food for predatory mites. A similar strategy allowed a preventive control of *Aculops lycopersici* with *Transeius montdorensis* on tomato. In this study, a methodology has been developed based on the examination of the nutritive profiling of factitious preys using the application of metabolomics. New quality indexes have been designed to select novel mixed and balanced diets considering the nutritional requirements of each predator. A unique diet composed of three astigmatid mite species with a nematode (*Panagrolaimus*) improves the establishment of at least three groups of predators: (i) anthocorids, especially a new genetically selected strain of *O. laevigatus* (Oricontrol PLUS®), (ii) mirids (*Nesidicoris tenuis* and *Macrolophus pygmaeus*) and (iii) phytoseiids (*Amblyseius swirskii*, *A. andersoni* and *T. montdorensis*). This feeding system may help to develop more robust and resilient biocontrol strategies. As an example, its use to successfully control the invasive species *Thrips parvispinus*, which is an increasing problem in vegetables and ornamental crops, is discussed.

Session 4-O13 - Free session

Plant-mediated effects of yellow mealworm waste on the brown marmorated stink bugs: a potential contribution to IPM

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The brown marmorated stink bug, *Halyomorpha halys*, a polyphagous invasive pest originating in East Asia, entered Europe in 2007, causing severe economic losses across various crops. Managing this pest is challenging due to the limited availability of effective biological control agents and the limited efficacy of available insecticides. Consequently, frequent insecticide applications, at 7–10-day intervals, have become necessary in some cases, marking a four-fold increase compared to regular intervals. This hampers the established integrated pest management (IPM) operations for several crops, mainly because the potent pesticides targeting *H. halys* often pose risks to pollinators and natural enemies. The Asian egg parasitoid *Trissolcus japonicus* has been recognized as the primary biological control agent for *H. halys*. Furthermore, in Europe, adventive populations of *T. japonicus* were identified in Germany, Italy, and Switzerland. In Italy, 120,000 *T. japonicus* females were augmentatively field released. Yet, to support IPM and reduce reliance on chemical pesticides, there is a need for innovative, efficient strategies. This study explores the use of yellow mealworm (YMW) wastes containing chitin as soil amendments to investigate their plant-mediated effect on the survival and behavior of *H. halys*. The presence of YMW exuviae and frass significantly impacts stink bugs, leading to increased pest mortality and reduced preference for treated tomato plants compared to untreated control plants. These positive effects are most likely attributed to the nutrient-rich composition of the residual streams, chitin's presence promoting beneficial microbe activity, and the stimulation of induced systemic resistance in treated plants. However, the precise mechanisms governing these effects on the survival and behavior of *H. halys* remain unstudied. A deeper understanding of these mechanisms may optimize the utilization of insect residual streams to mitigate pest pressure and support biological control strategies.

Session 4-O14 - Free session

The predation success of *Phytoseiulus persimilis* on its preferred prey, the spider mite *Tetranychus urticae*, is strongly reduced under extreme heat stress

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Climate warming results in more frequent and longer incidences of extreme high temperature events such as heat waves. Heat stress may affect predator-prey interactions, when the two opponents have differential heat sensibilities. The predatory mite *Phytoseiulus persimilis* is used globally to control spider mites (*Tetranychus urticae*) both in the field and greenhouses since several decades and is very efficient in controlling spider mites under optimal thermal conditions. However, when developing under extreme heat waves, the female predator-prey size ratios shifted in favor of the prey, which may result in reduced predation success. Alternatively, the predator might be more aggressive under heat stress to compensate for water loss via increased predation. We evaluated these assumptions by rearing the predator and prey separately under mild (daily T_{max}: 32°C) or extreme heat stress (daily T_{max}: 38°C) from egg to adulthood, placed then single female predator couples on small bean leaf discs, and exposed them to constant temperatures (32°C or 38°C) corresponding to the T_{max} values during their juvenile development. The mites were videotaped over 90 min and the heat stress effects on prey survival and maximum velocities of predator and prey were analyzed. Prey survival was significantly higher under extreme heat stress (38°C). Furthermore, maximum velocity of prey was not affected by heat and time, whereas maximum velocity of the predator decreased over time. Compared to prey, the maximum velocity of the predator was only higher within the first 15 min under 38°C, but was then lower after 45 min. These species-specific shifts in velocity increased the ability of prey to escape an attacking predator. Consequently, we argue that these behavioral modifications in conjunction with morphological shifts (lower predator-prey size ratios under extreme heat waves) were responsible for the low predation success under extreme heat stress.

Session 4-O15 - Free session

A novel formulation of entomopathogenic fungi that facilitates horizontal transfer of spores and improves long-term viability in bait stations

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Commercial products containing entomopathogenic fungi (EPF) are typically sprayed as aqueous suspensions onto target pests and crops. EPF in aqueous suspensions do not persist for long periods because absorption of water can lead to spontaneous germination of spores within hours. Therefore, when combined with the detrimental effect of sunlight on spores in the field, aqueous suspension applications have low persistence. For the use of EPF in bait stations, the spores must persist for days or weeks. Bait stations can effectively shelter EPF from rain and sunlight, thereby allowing powder EPF formulations and actively growing EPF on media to persist longer. However, these dry spore applications tend to be less effective and they are still affected by high humidity. Here, we describe a novel oil-based EPF formulation for use in bait stations and other attract-and-kill applications. Oil-based formulations can protect EPF from moisture and facilitate pickup of spores by insects. We demonstrate the effectiveness of the EPF (*Beauveria bassiana*) formulation on three species of Tephritidae fruit flies: Mediterranean fruit fly (*Ceratitis capitata*), oriental fruit fly (*Bactrocera dorsalis*), and melon fly (*Zeugodacus cucurbitae*). The treated bait stations, which contained male lures, facilitated contact of males of each species with the formulation. The males then transferred the spores to reproductively mature females during mating, leading to the control of both males and females.

Session 4-O16 - Free session

Bioprospecting of microorganisms for the management of the bacteria *Ralstonia solanacearum* race 2, causal agent of bacterial wilt disease (Moko) in banana

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Bacterial wilt caused by the *Ralstonia solanacearum* race 2 bacteria, also known as Moko, is one of the most problematic diseases that affects banana crops. This disease generates an economic, social, and environmental impact, due to production losses, high costs in eradication processes, quarantines, recovery of planting areas, vandalism and increase in the use of pesticides. In this sense, the use of microorganisms as biological control agents could be an alternative for the sustainable management of *R. solanacearum*, as well as a contribution to the ecological balance of soil microbial populations. Therefore, in this research, sampling was carried out at the level of a commercial farm with a high incidence of Moko disease, from which 60 microorganisms were isolated and evaluated at the *in vitro* level, to determine the potential biocontrol against *R. solanacearum*. In total, 26 microorganisms generated inhibition in the growth of the bacteria, of these, the COR-CB-021 and COR-CB-022 isolates were the ones that presented the best results with an average of 40 and 50% inhibition, respectively.

Session 4-O17 - Free session

Modelling mortality factors and natural enemies of fall armyworm in Zambia

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Fall armyworm (FAW), *Spodoptera frugiperda*, has been detected in Zambia late 2016. Since then, collective efforts to survey for local natural enemies is ongoing in the country in order to develop biocontrol programmes. Local natural enemies can play a role in suppressing a new invasive species, however, their contribution to the pest mortality should be quantified in order to justify introduction of exotic natural enemies. This research investigated the mortality factors of FAW over two rainy seasons in Central province of Zambia. As a first step, we modelled the abundance trends of FAW natural enemies through time and investigated possible factors contributing to explaining their abundance, namely temperature and relative humidity. Relations between abundance and environmental variables are not expected to be linear because organisms have optimal conditions. From preliminary analysis, models indicate that egg parasitoids and fungus are more abundant towards the end of the rain season. The second analysis estimated the impact of the most abundant parasitoids on the growth FAW populations at the start of the growing season.

Session 4-O18 - Free session

Functional response and host stage preference of mealybug parasitoids of the genus *Anagyrus*

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The efficiency of a parasitoid as a biocontrol agent of a pest is tightly linked to the behavioral response to factors such as host density. Three different types of functional responses have been described for arthropods, depending on the relationship with their prey or hosts. The functional response describes the relationship between host density and the rate of attack by a parasitoid. This knowledge will provide crucial information of the parasitoid regulatory effect on the pest population.

We evaluated the responsiveness of the parasitoid *Anagyrus aberiae* (Hymenoptera: Encyrtidae) to different host stages and host densities of the mealybug *Delottococcus aberiae* (Hemiptera: Pseudococcidae). These aspects will provide new insights into the performance of the parasitoid and its potential in controlling and regulating citrus mealybug populations.

Results show that *A. aberiae* prefers latter developmental stages of *D*. *aberiae*, with a higher rate of female mealybugs parasitized. Parasitism rate of *A. aberiae* increased with mealybug density, until a saturation point at which further increase of host density did not lead to a higher parasitism rate. This behavior is a common pattern observed among other parasitoids. Our results suggest that *A. aberiae* is likely to be a good biocontrol agent, especially in cases where the mealybugs populations densities are not excessively high.

Session 4-O19 - Free session

Post-introduction redistribution of biological control agents: best practices, risks and benefits

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Existing regulations and guidelines focus on building scientific justifications to evaluate the risks and benefits of first-time introductions of exotic biological control agents. In parallel, adventive introductions of natural enemies are now common. An emerging paradigm in biological control, and one that may become much more common due to increasing movement of exotic organisms, including biological control agents, due to global trade, are programs that seek to redistribute established agents to new areas of their host's novel range. Where there is no clear regulatory oversight for redistributions once an exotic biological control agent has established (i.e. within a nation), there is a need to develop best practices around the redistribution of these agents, in particular those species that were either not approved for intentional release, or were not subjected to modern standards of host specificity testing. We provide an overview of the ecological, geographic, and regulatory factors to consider when proposing to intentionally redistribute an established exotic biological control agent within continents, countries, and smaller jurisdictions. We also examine several ongoing biological control programs in Canada, a geographically vast country that has many examples where redistribution of biological control agents within its borders may be advantageous for pest management.

Session 4-O20 - Free session

Incongruent range limits of invasive spotted knapweed (*Centaurea stoebe* ssp. *micranthos*) and key biological control agents results in high elevation refugia

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Variable biological control of broadly distributed invasive species is a common pattern. In western North America, spotted knapweed (*Centaurea stoebe* ssp. *micranthos*) is a widespread and problematic invader of rangeland and urban areas and so has been subject to biocontrol since the 1970s. By the early 1990s, the North American knapweed biocontrol programme had led to the release of 13 insect agents, and eventually widespread reductions in its density and fecundity. Yet, pockets of abundant spotted knapweed remain. As any invader expands its range, it colonises new environments, posing challenges for introduced control agents, which may have experienced severe genetic bottle-necks during testing, importation and release, and/or have been sourced from climates that do not match the expanding environmental distribution of the target. We have previously shown that among 20 long-term monitoring sites, the abundance of key knapweed agents (*Larinus* spp. Curculionidae, Coleoptera) is positively related to growing season length, resulting in reduced attack rates in colder sites. To more carefully investigate this pattern, we monitored spotted knapweed and *Larinus* spp. at a total of 30 sites distributed along three, >1000 m elevational transects, visiting each site weekly through the 2022 growing season. We found that the abundance and attack rates of key biocontrol agents dropped sharply more than 300 m of elevation below knapweed elevational limits, and that this corresponded with increasing knapweed density and fecundity with elevation. As a result, we infer that short-growing season sites may act as refugia from key biocontrol agent species in the spotted knapweed system. More generally, biocontrol agents must be able to track their targets as their distributions expand. Employing species range limit theory to clarify where and why biocontrol may be limited will be critical to achieve control when targets are environmentally and spatially widespread.

Session 4-O21 - Free session

Agents sans frontiers: cross border aquatic weed biological control

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Biological control is an effective way of controlling invasive aquatic plants, and South Africa has been very active in this field, having released 15 agent species against eight aquatic weeds. South Africa shares waterways with six neighbouring countries, and thus it is highly likely that these agents have been inadvertently introduced to these countries. We assessed the status of these aquatic weeds in seven rivers across southern Mozambique and recorded whether any biocontrol agents were present. The weevils *Neochetina eichhorniae* and *N. bruchi* were recorded on water hyacinth in Mozambique, along with the pathogen *Acremonium* and the mite *Orthogalumna terebrantis*. The weevil *Neohydronomus affinis* was found in small populations on *Pistia stratiotes*, and the weevil *Stenopelmus rufinasus* was found on *Azolla cristata.* No agents were present on *S. molesta*. Further, we recorded *S. rufinasus* on *Azolla filiculoides* in Zimbabwe. These agents are likely to have dispersed from South Africa, and the rivers of southern Mozambique and Zimbabwe are likely to be benefitting from the transnational dispersal of these agents, but there is the need to develop best practices to ensure the safe use of biological control in sub-Saharan Africa.

Session 4-O22 - Free session

Potential of endophytic *Beauveria* spp. for growth promotion in blueberries and protection against *Neofusicoccum parvum* disease

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Neofusicoccum parvum (*Np*) is a wood pathogen that affects blueberry crops. To control it, chemical fungicides with low effectiveness are used. Endophytic fungi could be an alternative to protect plants and stimulate their growth. Seven strains of the genus *Beauveria* were identified at the species level. The endophytic colonization capacity of the strains in blueberry plants, the solubilization of phosphate and potassium, and their antagonistic activity *in vitro* were evaluated. For endophytic colonization, the percentage of colonization (PCE) was estimated by culturing parts of the plant. To measure promotional attributes, the phosphate and potassium solubilization indices in solid media were determined. For the antagonistic capacity against *Np*, dual culture method was used. One hundred percent of the strains endophytically colonized the blueberry. Strains RGM 657 and RGM 557 solubilized phosphate, and strains RGM 557 and RGM 2354 solubilized potassium. Strain RGM 570 demonstrated the highest PICRP with 35.51%. Strains of the genus *Beauveria* spp. endophytes are an alternative for promoting blueberry growth and have potential for protection against *N. parvum*.

Session 4-O23 - Free session

Arbuscular mycorrhizal fungi and soil organic carbon as tools to enhance crop yield

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Arbuscular mycorrhizal fungi (AMF) help plants acquire P from soil, which is a key nutrient for plant growth. Understanding which factors drive AMF-supported nutrient uptake is essential to develop more sustainable agroecosystems. Increasing soil organic carbon (SOC) can have positive effects on crop yield while contributing to mitigate climate change. Local studies reveal contrasting effects of SOC on crop yield, while a comprehensive field assessment across climatic conditions and soil types remains to be done. Here we collected soils from 150 cereal fields and 60 non-cropped grassland sites across a 3,000 km trans-European gradient. First, we tested the ability of AMF in these soils to forage for the radioisotope 33P from a hyphal compartment in a greenhouse experiment. Then, we quantified the role of SOC as a driver of cereal yield compared with climate and farming practices. AMF communities in grassland soils were much more efficient in acquiring 33P and transferred 64% more 33P to plants compared with AMF in cropland soils. The use of fungicides and subsequent decline in AMF richness in croplands reduced 33P uptake by 43%. Our findings also indicated that SOC positively relates with cereal yield, surpassing the magnitude of farming practices and climate variation. However, a notable leveling-off effect emerged at approximately 2% SOC. Our results suggest that land-use intensity and fungicide use are major deterrents to the functioning and natural nutrient uptake capacity of AMF in agroecosystems, and SOC can play a positive role on crop production across European cereal fields.

Session 4-O24 - Free session

Develop synthetic biology-based platform for efficient biomanufacturing of natural product pesticides from *Streptomyces* species

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Our team mainly focuses on discovery of *Streptomyces* with outstanding ability of biological control, identification of the major effective components and understanding of the regulatory and metabolic mechanisms controlling their biosynthesis, as well as high-yield strain engineering based on these new understandings. *Streptomyces* as the major industrial producer of natural product pharmaceuticals has complex morphological differentiation and natural product biosynthetic process, which are tightly controlled by orchestrated regulatory networks. Therefore, titer of target natural products is generally too low to fulfill the requirements for industrialization and application. To address this issue, we have developed synthetic biology based high-yield strain engineering platform for *Streptomyces*. We have deciphered several key regulatory and metabolic mechanisms that significantly affect biosynthesis of polyketide pesticides from *Streptomyces*, based on these new understandings, we then developed genetic part libraries (e.g. promoters and transporters), high-throughput strain screening approaches, metabolic pathway reconstruction and coordination strategies to advance construction of high-yield producers. By using these genetic parts and engineering strategies, we have developed several *Streptomyces* natural product pesticide cell factories. For example, titer of milbemycin A3/A4 was boosted to over than 4 g/l in *Streptomyces bingchenggensis*, titer of avermectin was enhanced to 9.31 g/l in *Streptomyces avermitilis*, and titer of guvermectin was improved to 2.5 g/l in *Streptomyces caniferus*. The synthetic biology-based *Streptomyces* development platform is useful to deepen our understandings of complex regulatory and metabolic mechanism of this species, and could also provide useful tools and strategies to develop other *Streptomyces* high-yield producers.

Session 4-O25 - Free session

Mass rearing, storage and application of natural enemy insects

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Biological control by augmentation of natural enemy insects (parasitoids and predators) that have been mass-produced in insectaries is a key component of integrated pest management strategy, and it is an effective, sustainable and ecologically friendly approach to suppress pest populations at the desired levels. Developing cost-effective mass rearing techniques is essential for improving biological control programs, especially those based on inundative and seasonal inoculative releases. China has a long history of biological control. Up to now, more than 40 species of natural enemies that can be artificially mass-produced and the annual average application area of natural enemies is over 11.34 million hectares in China. Here we introduce the development of mass rearing techniques of natural enemies, including the use of alternative hosts and artificial diets to mass-produce natural enemies and the extending of storage period through diapause manipulation. Some successful examples of field protection and application of natural enemies in China are presented, including case studies on the use of *Arma chinensis* in tobacco and crop fields. Although many natural enemy species can be mass-reared, the mass production still faces problems such as high economic costs, low efficiency, low automation and mechanization of the rearing processes and difficult to control quality. With the increased desire of high-quality and safe agricultural products, the requirement for biological control is growing. It is necessary to study basic bioecological characteristics of natural enemies, mass rearing techniques, continual maintenance of insect populations, long-term storage and shipment approaches, and release techniques (e.g. release time, release point and release quantity), etc. This is of great significance for comprehensively promoting the application of biological control and sustainable agricultural development.

Key words: Biological control; natural enemy insect; mass rearing; diapause regulation; augmentation release

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Session 4-O26 - Free session

Evaluation of the potential biocontrol ablity of a native natural enemy, *Nesidiocoris poppiusi*, against *Tuta absoluta* in China

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Tuta absoluta (Meyrick) was first found in Yili city, Xinjiang in August 2017, and has occurred in 20 provinces in China until 2023, causing huge losses to China's agricultural economy. With the colonization of *T. absoluta* in China, finding and using local natural enemies for biological prevention and control of *T. absoluta* has become an important work for the sustainable management of *T. absoluta* in China. *Nesidiocoris poppiusi* is a new native predator in China belonging to the family Miridae, which shares morphological characteristics with *Nesidiocoris tenuis*. We hypothesized that it could also be used as a predatory natural enemy of *T. absoluta*. In this study, we firstly elucidate the predation preference of *N. poppiusi* over different stages of *T. absoluta*. Subsequently, the life history traits of *N. poppiusi* on *T. absoluta* eggs were investigated. We found that *N. poppiusi* is capable of effectively preying on both eggs and larvae of *T. absoluta*, when eggs and larvae of all ages are present, adult *N. poppiusi* has a clear preference for *T. absoluta* eggs and 1st instar larvae. Meanwhile, *N. poppiusi* could develop and reproduce on *T. absoluta* eggs, and the nymphs could prey on *T. absoluta* eggs from the beginning of hatching until the death of the adults. The nymph stage of *N. poppiusi* was 14 days, and the total number of predation during the nymph stage was 584. The adult life span of *N. poppiusi* was 28.47 days for females and 26.70 days for males. The average amount of predation of each female was 1754.93 eggs per adult stage, while the average amount of predation of each male was 1333.70 eggs. In summary, *N. poppiusi* can be a promising predominant natural enemy to *Tuta absoluta*.

Session 5-O1 - Risk assessment of cactus pests and weeds

Selecting the most damaging biocontrol agents for invasive alien Cactaceae in sub-Saharan Africa

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Several species of cactus are problematic invasive alien plants in sub-Saharan Africa. These cacti reduce grazing capacity, restrict the movement of livestock and wildlife, and threaten indigenous biodiversity. Very few cactus species in Africa are valued, there is only one indigenous cactus species on the continent, and just three alien species are utilized as crops. This makes the invasive cacti on the continent excellent targets for biological control because there are very few closely related non-target plant species. Most cactophagous insects are therefore appropriate biocontrol agents in terms of their host specificity. There are however significant complications in selecting agents that are suitably damaging to the target weed. Many cactophagous insects develop local adaptations to certain plant genotypes and climates, so there are several historical and contemporary examples of mismatches between the target weed and the agent that have hampered cactus biocontrol programmes in Africa. The results of recent bioassays to select effective agents for three cactus weeds in southern Africa (*Opuntia elata*, *Cylindropuntia pallida* and *Trichocereus spachianus*) have helped select damaging lineages of biocontrol agents for these invasive pests, and have shown how nuanced and complicated the selection of the most effective agent can be.

Session 5-O2 - Risk assessment of cactus pests and weeds

Cogongrass (*Imperata cylindrica*) diversity and native range exploration for herbivores

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Cogongrass, *Imperata cylindrica* (Poaceae), ranks among the top 10 global weeds and has become the target of a biological control program in the southeastern US. However, prioritizing regions for agent exploration and evaluation presents challenges due to the morphological and genetic diversity of *I. cylindrica* across its native and invasive ranges. Further, the native distribution of this grass spans Africa, Asia, Europe, and Oceania, yet the origins of invasive US populations are only partially resolved. Our surveys of *I. cylindrica* across Australia, Japan, and South Korea have so far revealed an unexpectedly high herbivore diversity, with over 60 species identified feeding on flowers, stems, shoot tips, or rhizomes. This presentation will synthesize the existing molecular and taxonomic literature on *I. cylindrica* diversity, explore its relationship with the most promising herbivores that have been identified to date, and cover the broader implications for how this biological control program proceeds.

Session 5-O3 - Risk assessment of cactus pests and weeds

Biological control of the invasive grass cogongrass, *Imperata cylindrica*

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Cogongrass, *Imperata cylindrica*, is one of the ten worst weeds in the world impacting agriculture, forestry, and biodiversity. Options to control this invasive weed are limited to synthetic herbicidal compounds which provide only temporary relief requiring annual retreatments. We are developing ecologically safe, sustainable, and cost-effective control of cogongrass through the development of biological control agents. Our research seeks to identify the origin of the invasive lineages of *I. cylindrica* with molecular approaches and prioritize surveys for potential agents in the areas with the closest matches and where the weed originates. One of the invasive lineages invading the southeastern USA comes from Japan. Despite the traditional view that grasses have low herbivore diversity, we have recovered over 60 species of potential agents in Japan and Australia. These include a diverse assemblage of herbivores that feed on different plant tissues including flowers, stems, shoot tips, and rhizomes. Two agents have been prioritized, a stem borer *Emmalocera latilimbella* (Lepidoptera: Pyralidae) and a shoot tip borer *Atherigona* sp. (Diptera: Muscidae) which have been colonized and are currently undergoing host range testing in quarantine in the US. Preliminary tests indicate that both are specific and may provide significant control of the target weed. Further testing will determine if these species can be promoted for safe and effective biological control of *I. cylindrica*.

Session 5-O4 - Risk assessment of cactus pests and weeds

Exploring the safety of two parasitoid candidates for the biological control of the cactus mealybug *Hypogeococcus* sp. in Puerto Rico

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Hypogeococcus sp. is devastating native and endemic cacti in Puerto Rico. Initially, this insect was thought to be *Hypogeococcus pungens* Granara de Willink (Hemiptera: Pseudococcidae), a species native to South America that fed on several plant species within the Cactaceae, Amaranthaceae, and Portulacaceae families. However, it is now acknowledged that *H. pungens* is a species complex, and that the Puerto Rican pest is derived from Brazilian cactus-feeding mealybugs. Without effective control measures, the pest poses a continuing threat to Puerto Rican dry forest and cactus-rich ecosystems across the Caribbean islands, Central America, and North America. To counteract this problem, a classical biological control program was initiated in Argentina to identify host-specific natural enemies of "*H. pungens*". Upon confirming that *H. pungens* is a species complex, the search for natural enemies extended to Brazil and Paraguay. *Anagyrus cachamai* Triapitsyn, Logarzo & Aguirre and *A. lapachosus* Triapitsyn, Aguirre & Logarzo (Hymenoptera: Encyrtidae), native to Argentina and Paraguay, were identified as the most promising candidates for controlling the pest *Hypogeococcus* sp., leading to the transition of control efforts into a "new association" biological control program. These species were selected because they exhibited high levels of parasitism in *Hypogeococcus* spp. hosts during field collections, and they were absent in Puerto Rico. Laboratory host range tests in the native range support the field evidence, and this is crucial, given that there are not native species of the *Hypogeococcus* genus in Puerto Rico. Specificity tests were initiated in quarantine facilities of Puerto Rico, and thus far, the parasitoids have shown an inability to produce viable offspring on non-*Hypogeococcus* hosts. The establishment of stable populations of these parasitoids as natural enemies is expected to alleviate the damage caused by the pest in Puerto Rico's dry forests.

Session 5-O5 - Risk assessment of cactus pests and weeds

Assessing the potential of parasitoids as biocontrol agents for the cactus moth, *Cactoblastis cactorum* in Argentina and North America

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The cactus moth, *Cactoblastis cactorum* (Lep: Pyralidae) is native to South America and has been used as a biocontrol agent of *Opuntia* (Cactaceae) in Australia and South Africa. However, its invasion in North America has raised concerns for the native *Opuntia*. Moreover, it is also a pest of cultivated *O. ficus-indica* in Argentina, its native range. We investigated the potential of two parasitoids as biocontrol agents. The first, *Apanteles opuntiarum* (Hym: Braconidae) is a common natural enemy native to Argentina. This gregarious larval endoparasitoid was studied in the laboratory to understand reproductive biology, determine host range, and develop rearing protocols. Our findings suggest that host defensive behavior and interactions with the cactus may play an important role in per-host wasp production. We also found that parasitism and mortality rates were higher at lower host densities, possibly due to reduced host group defensive behavior. Currently, the petition for the release of *A. opuntiarum* in the USA is under revision, and pre-release experiments in the native range are in progress. The second parasitoid, *Goniozus legneri* (Hym: Bethylidae), is a generalist ectoparasitoid that is used in inundative biological control programs against lepidopteran pests in Argentina. We assessed the *C. cactorum* mortality caused by *G. legneri* at different spatial scales. We found that the most important mechanism involved was the paralysis of the larvae, which reduced larval damage to the plants by 85%. We also investigated the interactions between the two parasitoids. The combined mortality caused by both parasitoids was higher than a single one, especially when *G. legneri* arrived first, suggesting asymmetric competition due to the preference of *G. legneri* attacking previously parasitized larvae. Therefore, *G. legneri* has the potential to be an inundative biocontrol agent of *C. cactorum* in Argentina, but its interaction with the classical biocontrol agent *A. opuntiarum* needs to be considered.

Session 6-O1 - Molecular tools in biological control

How ecological networks revealed by DNA metabarcoding may help in biological control programs? The case study of *Sonchus oleraceus* in Australia

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In this study, we used an approach based on molecular technologies to infer interactions between plants, herbivores and their natural enemies and reconstruct ecological networks occurring in both the native (Europe) and the introduction range (Australia) of the weed *Sonchus oleraceus* (Asteraceae). Our objectives were to assess differences (i) in the richness and abundance of herbivores, (ii) in herbivory pressure on *S. oleraceus* through varying levels of damage and vigour, and (iii) in the structure of the ecological networks.

During spring 2018, all arthropods associated to *S. oleraceus* and to surrounding vegetation were sampled within 1 m² quadrat for one hour in several sites located in France and Australia. In each quadrat, a set of traits were measures on *S. oleraceus*. In France, a total of 2834 arthropods specimens were collected, while 1938 were sampled in Australia. Interactions revealed by metabarcoding (CO1 markers) were aggregated into two distinct interaction networks, for the native and invaded range, to maximize the proportion of links occurring in each range.

First results show that the species richness of herbivore feeding on *S. oleraceus* is higher in its native range than in its introduction range, which translates into more diversified modes of plant exploitation. At network scale, 45% of the plant species in the native range are consumed by at least one herbivore species, this is almost 15% less in the invaded range. The average plant community vulnerability is lower in invaded range, meaning that plants share less interaction with herbivores in Australia than in France. This may be explained by the fact that of the 29 plants identified in Australia, only one is a native species, and herbivore cortege may not be adapted to these plant communities. In the frame of invasive plant species control, the introduction of biocontrol agents would be fully justified. Deeper analyses of these networks may also offer perspectives in indirect risk assessment.

Session 6-O2 - Molecular tools in biological control

PhyloControl: a phylogeny visualisation interface for risk analysis in weed biological control

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Phylogenetic distance is a key measure used to develop host test lists that will delimit the fundamental and realised host range of candidate biocontrol agents. Plant pathogens and insects, even those with broad host ranges, exhibit some degree of phylogenetic conservatism in their host plant associations. Thorough testing is crucial to minimise the risk of off-target damage by biocontrol agents to native and economically important plant species. To facilitate this, host test lists need to be developed from an understanding of evolutionary relationships, usually visualised as a phylogenetic tree generated from genetic data, together with plant functional traits and geospatial information. Currently, the process of obtaining a host test list is not standardised, and the manual steps are time-consuming and challenging. We have developed a prototype user-friendly visualisation tool called PhyloControl to aid biocontrol researchers in their decision-making during host test list development. PhyloControl integrates taxonomic data, molecular data in the form of phylogenomic trees, spatial data, and plant traits in an intuitive interface, empowering biocontrol practitioners to summarise and analyse data efficiently. Comprehensively sampled phylogenetic trees are often unavailable, and older published phylogenies based on Sanger data often lack branch resolution and support, which increases uncertainty. PhyloControl includes a workflow allowing users to download publicly available DNA sequences and perform phylogenetic analyses. Additionally, the tool incorporates species distribution modelling to predict the current and potential extent of target weed species and how their distributions may shift under future climates. The interface will streamline the development of biocontrol host tests lists to support risk analysis and decision making in classical weed biological control.

Session 6-O3 - Molecular tools in biological control

Applying novel primers as a tool for determining the ligustrum weevil's (*Ochyromera ligustri)* impact on invasive Chinese privet

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Chinese privet, *Ligustrum sinense*, is a highly invasive shrub to southeastern United States forests. It is highly prolific, with dense root systems and massive seed banks. The relatively recent discovery of the exotic seed predator, the ligustrum weevil (*Ochyromera ligustri*), may have potential as a biological control agent of the invasive plant. The weevil is native to Asia and was unintentionally introduced into United States in the ornamental trade in the 20th century. It is currently found throughout most of the Chinese privet's adventive region in southeastern US, from Texas to New York. The weevil may limit reproduction of privet by larvae developing inside the seeds. PCR primers recently developed at the Louisiana State University Biocontrol Lab will be a powerful tool in understanding the impact of this weevil's presence in the United States. Using the polymerase chain reaction (PCR) technique using the primers, we can rapidly and accurately detect the presence of the ligustrum weevil within berries to learn more about the weevil's distribution and host range, as well as the impact on Chinese privet. By obtaining privet berries and collecting presence or absence data of ligustrum weevil DNA in them using the PCR technique, we can determine regions where the weevil is present, within which plant species the weevil is attacking, and the proportion of berries attacked per tree. Berries will be collected through citizen contribution as well as field collections. This project will fill in these gaps in knowledge to further the understanding of the ligustrum weevil's part in the control of Chinese privet as a potential biological control agent, or as a potential pest to other plant species in southeastern US.

Session 6-O4 - Molecular tools in biological control

Molecular diagnostics reveal both landscape pattern effects and functional redundancy in whitefly-predator food webs

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Generalist predators have the potential to provide biological control services for the whitefly, *Bemisia tabaci*, but their feeding on alternative prey may reduce efficacy. Review of generalists suggests at least 30 generalist predator species feed on whiteflies. And, diverse communities may contribute to regulation of *B. tabaci* in landscapes of cotton and vegetable production. However, challenges remain as vegetable-cotton landscapes contain risky areas of highly intensive management and frequent application of insecticides. Here we provide an overview of studies at the field level for unraveling food webs of generalists within whitefly systems, and zoom out to the landscape level to reveal patterns of landscape dependence on whitefly regulation and generalist predator use of alternative prey.

Session 6-O5 - Molecular tools in biological control

Tillage effects on trophic interactions in carabid communities and their implications for biological control

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The study of food webs is essential for understanding ecological interactions that govern the provision of ecosystem services such as natural pest regulation that are crucial for sustainable agriculture. Generalist predatory arthropods such as carabid beetles (Carabidae) play a critical role in natural pest regulation in agroecosystems. However, their efficacy as biological control agents is susceptible to challenges, including preferential consumption of non-pest alternative prey and intra-guild predation (IGP). Moreover, major agroecosystem disturbances caused by farming practices such as tillage have a strong impact on arthropod assemblages, habitat structure and agroecosystem stability, which can significantly alter trophic interactions in predator communities. In this study we employed molecular gut content analysis to evaluate the effects of tillage on carabid food web structure in cereal fields in Austria, with an emphasis on IGP among ground-dwelling arthropods. Prey DNA was extracted from carabid regurgitates and analyzed using diagnostic multiplex PCR assays to determine the detection frequency of target intra-guild and extra-guild prey groups. The anticipated results are poised to unveil key food relationships among agroecosystem invertebrates that may have major implications for natural pest suppression. This knowledge can help inform sustainable farming practices by substantiating their effects on trophic interactions that affect ecosystem services in agricultural fields.

Session 6-O6 - Molecular tools in biological control

Potential RNA mediated control of global pest, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae)

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Cotton whitefly, *Bemisia tabaci*, is a serious global polyphagous pest which is difficult to control through commercially available methods. Though lot of work has been done on the management of whitefly using traditional methods, there is a need for the novel RNA interference based management strategies. Thus, a new approach has to be explored as a potent method for the whitefly management. RNA interference (RNAi) is a one such approach which is highly conserved, sequence specific mechanism of gene silencing triggered by the admission of double stranded RNA (dsRNA). Genes like *acetylcholine esterase* (AChE), *vATPases* (A, D and E) family of ubiquitous proton pump and *aquaporins* (1,2,4,9 and 12) family of membrane water transporters) and *chitin synthase* (CHS) were selected as targets for siRNA mediated gene silencing. The target sequences were amplified using specific primers from the cDNA of adult whitefly and was cloned in L4440 vector for *in vitro* synthesis of dsRNA. To assess the mortality of adult whitefly, 15% sucrose was used for parafilm sandwich based *in vitro* assays. Target dsRNA in concentration of 5, 10, 20 and 40 ng/ul was mixed with 15% sucrose and fed to whiteflies and the adult mortality was assessed at 24, 48, and 72 h after feeding. After 72 h of feeding *vATPase E* and CHS *synthase* showed maximum mortality of >85%, AChE, aquaporins showed the mortality of approximately 60–75% and *vATPase* D and *aquaporins 2* and 9 with mortality of <50%. Silencing of the target gene was also confirmed through qRT–PCR gene expression analysis and the result showed the mRNA degradation of > 70% in *vATPaseE* and CHS, *aquaporins* and AChE of equal to ≥ 50%. The target genes *vATPaseE* and CHS showed significant down regulation in correlation with highest mortality. Furthermore, the *vATPaseE* and CHS were formulated with nanohydrogels and resulted more than 80% mortality and RTPCR analysis of the above nanoformulations resulted mRNA degradation of 70% in *vATPaseE* and 60% in CHS. Efficacy of RNAi mediated gene silencing of these genes offers an opportunity for using them as potent target for the nanoformulation based biopesticides for the management whiteflies.

Session 7-O1 - Pre-emptive classical biological biocontrol

Pre-emptive classical biocontrol risk assessment for high-risk biosecurity threats: paving the way for implementation

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Non-native invasive insect species are threatening biodiversity and food security worldwide resulting in substantial economic, environmental, social and cultural costs. The threat is increasing because of factors such as the globalisation of trade, tourism and climate change. Many invasive insect species (e.g., brown marmorated stink bug, BMSB) are considered as high-risk biosecurity threats to our global biodiversity and food security, and if left unmanaged, can result in multi-billion dollar losses to agriculture and horticulture industries. Classical biological control (CBC) is frequently adopted as a cost-effective component of integrated pest management programmes for sustainable management of invasive arthropod pests. However, CBC programmes are traditionally initiated once a pest has established, and invariably take several years to achieve BCA approval and implementation, during which time pest impacts accelerate. A pre-emptive biocontrol approach provides an opportunity to develop CBC for invasive pests prior to their arrival in the country at risk of introduction, where natural enemies can be selected, screened in containment or overseas, and potentially pre-approved prior to pest establishment, thus, improving CBC efficiency. A critical aspect of this approach is that risk assessment is carried out in advance of the arrival of the pest. However, such an approach may not always be feasible (e.g., suitable natural enemies may not be available, logistic aspects may not allow this). Here, we will present the results of a pre-emptive classical biocontrol programme conducted in New Zealand against the brown marmorated stink bug, and we will discuss a decision framework that was developed to assess the feasibility of conducting pre-emptive risk assessment for classical biological control agents against high-risk insect pests. In addition, this presentation will highlight the importance of pre-emptive biocontrol as a key tool to enhance preparedness for high-risk pests.

Session 7-O2 - Pre-emptive classical biological biocontrol

Challenges & opportunities: implementing pre-emptive biological control in California

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Invasive arthropod species are a major threat to California's agricultural and natural resources. Biological control remains a key component of sustainable pest management programs for urban, natural, and agricultural ecosystems. This presentation will highlight and reflect on: (i) current classical biological control research projects targeting stink bugs (e.g., brown marmorated stink bug), wood-boring beetles (e.g., emerald ash borer), and moths (e.g., South American tomato pinworm), (ii) challenges with delivering timely biological control solutions against the backdrop of rising pressure from invasive species, (iii) the need for comprehensive pre-emptive biological control, and (iv) opportunities for dynamic stakeholder partnerships to expedite the delivery of pre-emptive biological control programs in California.

Session 7-O3 - Pre-emptive classical biological biocontrol

Assessing the feasibility of pre-emptive biocontrol against the emerald ash borer – a European case study

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The emerald ash borer *Agrilus planipennis* (Coleoptera: Buprestidae) (EAB) is a destructive wood-boring pest of ash trees (*Fraxinus* spp.). Originating from Eastern Asia it has been introduced into North America and European Russia, from where it is spreading towards European countries. Based on the North American experience with classical biological control against the beetle using natural enemies imported from Asia, one egg- and three larval parasitoids, we assessed the feasibility of pre-emptive biocontrol in Europe using a recently developed standard protocol. We first modelled the potential distribution of EAB and its natural enemies in Europe employing CLIMEX climatic suitability models. Next, we evaluated information on biological safety of the four agents in light of the Central European biodiversity, including non-target species, congeners and potential competitors. Finally, we addressed aspects of practicality, such as infrastructure and the regulatory environment in Switzerland that could accommodate a pre-emptive biocontrol program against emerald ash borer. Among the investigated agents we deemed pre-emptive biocontrol with *Oobius agrili* (Hymenoptera: Encyrtidae), *Spathius galinae* (Hymenoptera: Braconidae) and *Tetrastichus planipennisi* (Hymenoptera: Eulophidae) feasible, albeit certain information for a full risk assessment would still have to be gathered. The fourth species, *Spathius agrili,* we deemed unsuitable due to its largely unsuccessful establishment in climatically similar regions of North America. Although ultimately depending on regulatory decisions, no major practical hurdles for the import, quarantine research, registration process and release of the natural enemies were detected.

Session 7-O4 - Pre-emptive classical biological biocontrol

Classical biological control of the Japanese beetle, *Popillia japonica*, in Europe using the tachinid fly *Istocheta aldrichi*

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The Japanese beetle, *Popillia japonica* Newman (Coleoptera: Scarabaeidae) is native to East Asia and, early in the 20th century, it was accidentally introduced to North America, where it causes considerable damage. Adults defoliate a variety of trees and crops and larvae feed on the roots of various plants and grasses. In Europe, the beetle was first recorded in the 1970s in the Azores and in 2014 in Italy. It was first found in southern Switzerland in 2017 and quickly became a serious pest in vineyards and other crops. A classical biological control programme was initiated at CABI, funded by the Swiss Federal Office for Agriculture, before the beetle spread throughout the country and the rest of Europe. The first natural enemy considered for introduction into Europe is *Istocheta aldrichi*, a tachinid parasitoid of adult beetles, which is native to Japan and was introduced in the 20th century into North America. Puparia were imported from Canada thanks to a collaboration with the University of Montreal. A laboratory rearing was successfully established in CABI's quarantine laboratory. Our present research focuses on three major questions: (i) is *I. aldrichi* specific to the Japanese beetle? (ii) What are the climatic requirements of *I. aldrichi* as compared to its host? (iii) Will the phenology of *I aldrichi* be synchronized with that of the Japanese beetle in Europe? So far, *I. aldrichi* has never been found to attack other beetles in its native and introduced ranges, suggesting that it may be specific to *P. japonica.* In no-choice tests conducted in small cages, successful parasitism was observed on a few specimens of two other beetles of the same sub-family, which could indicate that its physiological host range may differ from its ecological host range. Models that are presently being built suggest that *I. aldrichi* and *P. japonica* will probably be able to establish in most of Europe but also predict a potential physiological mismatch between the phenology of the parasitoid and that of its host, i.e. adult flies are predicted to emerge earlier than adult beetles in early summer.

Session 7-O5 - Pre-emptive classical biological biocontrol

Assessing the potential of native *Anastatus* spp. (Hymenoptera: Eupelmidae) parasitoids for proactive biological control of *Lycorma delicatula* in California

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The spotted lanternfly (SLF), *Lycorma delicatula* (Hemiptera: Fulgoridae), is a generalist planthopper native to parts of the East Asian and the Indomalayan regions. In September 2014, the species was recorded for the first time in North America (Pennsylvania, USA) from where, despite quarantine and control efforts, it rapidly established and spread to many northeastern U.S. states. Substantial feeding damage has been observed in vineyards, leading in extreme cases to the complete loss of productivity. In California, where the wine and winegrape sector and allied businesses deliver a total economic contribution of more than $170 billion per year to the U.S. economy, the possible arrival of SLF could have a great impact on this world-renowned commodity. The only known egg parasitoid of SLF in its native range, *Anastatus orientalis* (Hymenoptera: Eupelmidae), is a generalist species with a broad host range, making it unsuitable as a classical biological control agent for use against SLF in the U.S. The aim of this project is to identify native parasitoids from the Chiricahua Mountains in southeastern Arizona, a biodiversity hotspot for U.S. fulgorids, that might have potential as biological control agents of SLF should it be accidentally introduced in California. In this proactive assessment measuring potential biotic resistance by native parasitoid species, we collected two species of native fulgorids and exposed their egg masses in the native area with the aim of collecting their natural egg parasitoids. After field exposure, egg masses were collected and maintained in controlled laboratory conditions in a quarantine facility, awaiting the emergence of parasitoids to be identified and tested on SLF egg masses. Moreover, the host range of the U.S. native *Anastatus reduvii* has been tested on eggs of other native species to identify potential additional taxa that can be used for sampling native parasitoids of the genus *Anastatus*. Results of these studies are presented.

Session 7-O6 - Pre-emptive classical biological biocontrol

Is *Anastatus reduvii* (Hymenoptera: Eupelmidae) a potential natural enemy for proactive biological control of the spotted lanternfly in California?

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The spotted lanternfly (SLF), *Lycorma delicatula* (Hemiptera: Fulgoridae), is an invasive planthopper that was first detected in Pennsylvania, US in 2014 and has subsequently spread rapidly throughout the northeastern US. Due to its polyphagous nature, SLF poses a significant risk to several important specialty crop industries in the US. Ecological modeling suggests that SLF would readily establish in many areas of California, US, where susceptible specialty crops, like nuts and grapes, are grown. Research from the northeastern US suggests that insecticidal control of SLF is not a viable long-term solution because established populations of the pest in forested or urban areas support rapid reinvasion of neighboring agricultural groves following insecticide treatments. Thus, our goal is to proactively develop a biological control method for SLF prior to its predicted invasion of California. Unfortunately, SLF's only known natural egg parasitoid, *Anastatus orientalis* (Hymenoptera: Eupelmidae), is a generalist and its broad host range makes it unsuitable for release in the US. However, one congeneric species native to the US, *A. reduvii*, can parasitize SLF eggs. Preliminary research suggests that *A. reduvii* exhibits a very low parasitism rate when presented with SLF egg masses. The goal of this work is to develop a rearing method that potentially improves the ability of *A. reduvii* to parasitize SLF eggs. To this end, we reared *A. reduvii* on eggs of several different host species and compared resulting female body sizes, fecundity, and parasitism rates on SLF egg masses. Our results suggest rearing methodology strongly affects the ability of *A. reduvii* to parasitize SLF eggs. It is possible, based on results obtained so far from quarantine studies, that *A. reduvii* may offer biotic resistance to invading SLF populations and mass-reared parasitoids may have potential for targeted release against small highly localized incipient SLF populations should they invade California.

Session 7-O7 - Pre-emptive classical biological biocontrol

Could biotic resistance contribute to future biological control efforts for brown marmorated stink bug (BMSB) in Aotearoa New Zealand?

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Halyomorpha halys (brown marmorated stink bug, BMSB) is a highly polyphagous invasive pest species (over 300 host plants recorded) and a major biosecurity threat to the sustainability of the multi-billion-dollar horticultural sectors and native estate of Aotearoa-New Zealand. A pre-emptive classical biological control programme for BSMB was initiated in December 2015, resulting in the approval for the release of the egg parasitoid *Trissolcus japonicus* in the event of BSMB's arrival.

Biocontrol programmes rarely rely on a single biological control agent (BCA). Therefore, evaluating additional BCAs that could be used alongside *T. japonicus* would maximise the effectiveness of a biocontrol programme against BMSB in native and crop ecosystems. This should further reduce insecticide dependence and positively contribute to existing integrated pest management programmes.

We are developing a series of strategies focused on biotic resistance by surveying the egg parasitoids present in Aotearoa-New Zealand and assessing the outcomes of interspecific competition between them and with *T. japonicus*. This will enhance our biocontrol preparedness for a potential BMSB invasion and contribute to minimise its economic, environmental, and social impacts in Aotearoa-New Zealand.

A three-year systematic field survey is being conducted by collecting wild pentatomid egg masses and deploying sentinel egg masses through pentatomid hot spots in targeted regions of Aotearoa-New Zealand. Our priority is to assess the presence/absence of *T. mitsukurii*, an egg parasitoid introduced in Australia in 1962 against *Nezara viridula* and known to be an effective parasitoid of BMSB. Furthermore, we will identify resident stink bug parasitoid populations. Preliminary results show that there are parasitoids and hyperparasitoids from the genus *Trissolcus* and *Acroclisoides*. In addition, we are conducting a series of bioassays to assess interspecific interactions between resident parasitoids and *T. japonicus* to determine if they could work in synergy.

Session 8-O1 - Use and preservation of parasitoids in agriculture

Parasitoid wasps recruitment by flowering plants for natural regulation of *Diaphania* sp. in cucumber cropping systems in the Caribbean

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Tropical agriculture is under constant parasite and pest pressure, and transition toward sustainable food production involves improving natural regulation, so as to lessen dependence on synthetic control inputs. Parasitoids are major agents of biological control, and could be attracted and locally recruited by habitat manipulation (agroecological approach of conservation control). This approach, while broadly studied worldwide, is still in little use in Guadeloupe and in the broader Caribbean region or in even diverse tropical contexts. We aimed to develop innovative cucumber systems integrating flowering plants locally to enhance parasitoid natural populations, in order to increase natural pest regulation. We focused on the main pest, *Diaphania* sp. in Guadeloupe. This study consisted in 4 steps: 1) *ex-ante* assessment of farmers' perception of conservation biological control and preferences about flowering plants in their fields; 2) evaluation of indigenous plant species for their ability to create favourable habitats for parasitoids communities 3) experimental analysis of agroecological cucumber systems integrating flowering plants with evaluation of pest damage, parasitoid-pest interactions, parasitism rate and yield 4) *in-situ* on farm evaluation of innovative cucumber pest management by comparing conventional plots *vs*. flowering plants plots.

Session 8-O2 - Use and preservation of parasitoids in agriculture

Can we manage honeydew to preserve parasitoids and increase their biological control services?

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Honeydew is the sugar-excretion product of plant-feeding hemipterans, such as aphids, coccids, whiteflies, and psyllids. Compared to other sugar sources present in agricultural lands, honeydew is highly accessible and abundant in nearly all crops and seasons. This sugar source is exploited by many biological control agents, including parasitic wasps. However, honeydew is not only consumed by parasitic wasps, but also by pests, hyperparasitoids and ants. Besides arthropods, many fungi and bacteria grow on honeydew in agroecosystems, changing its composition. Therefore, honeydew mediates the interaction between parasitic wasps and other organisms in agricultural crops. These interactions may affect directly or indirectly the honeydew producer and the parasitic wasp in both a positive and negative way. Herein, we first review the main ecological interactions driven by honeydew as a food source and as a semiochemical. Then, we propose several strategies to exploit this knowledge and improve the fitness and abundance of parasitic wasps used in biological control of pests in agriculture.

Session 8-O3 - Use and preservation of parasitoids in agriculture

Use and preservation of parasitoids in agriculture: challenges and potential

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The use of egg parasitoids to control bugs from the Pentatomidae family is a valuable tool for agriculture, showing positive results in both the environmental and agronomic spheres. In the environmental sphere, the use of control agents that do not generate waste in the agroecosystem and are capable of becoming part of its interaction, fully complying with the precepts of sustainable agriculture. In terms of agronomy, egg parasitoids present several characteristics that highlight them as an agent for controlling pest insects, mainly the ability to search for the pest, since these insects are attracted to volatiles emitted both by the egg phase and by the adult of the insect pest. Furthermore, they are capable of providing control even before the pest is capable of causing injuries to the plant, thus positioning themselves prominently in crops that do not tolerate injuries without generating economic damage. Therefore, the current and future scenario requires the optimization of existing products based on egg parasitoids as well as the discovery and registration of more products based on these insects, so that it is possible to control the largest possible number of insect pests, in the most diverse cultures, in addition to providing the industry's evolution in large-scale production capacity. Aligning opportunities and challenges at the same magnitude, as agriculture's demand for these tools increases exponentially, it is extremely important that public and private research institutions and industry are able to keep up with growth proportionally. So that expectations and meeting demand are compatible in a positive way. Finally, understanding the positive results and bottlenecks found in the use of egg parasitoids is necessary to achieve the results desired by agriculture.

Use of *Diadegma semiclausum* as a biocontrol agent against diamondback moth in California: potential and challenges

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The diamondback moth (DBM) *Plutella xylostella* is a worldwide pest of cruciferous crops such as cabbage, broccoli, and cauliflower. This insect is notorious for its ability to develop resistance to various insecticides, making pest management challenging. Here we present the results of a study aiming evaluating the potential of the European parasitoid *Diadegma semiclausum* for introduction biological control of DBM in California. Three populations of *D. semiclausum* originating from different European countries were compared for their performance against DBM populations under quarantine conditions. Parasitism rates were also evaluated under semi-realistic field conditions, and competition with the American parasitoid *Diadegma insulare* was investigated. Results showed that all populations could successfully develop in DBM populations from California, including a population resistant to insecticides, and that switching from their original DBM population to a Californian DBM population did not cause a drop in performance, except with the pesticide-resistant populations, for which mortality of parasitized caterpillars was higher. Under semi-realistic conditions, *D. semiclausum* was effective at finding its host on several *Brassica* cultivars commercially important in the USA. Overall these results are clearly promising for a potential future introduction of this parasitoid in California. Host-specificity testing will be the next important step of this classical biological control program.

Session 8-O5 - Use and preservation of parasitoids in agriculture

Unravelling the factors determining the efficacy of mealybug parasitoids

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Invasive mealybugs pose a threat to tropical and subtropical crops. Parasitoids are considered to most effective biological control agents of mealybugs, however, the efficacy of parasitoids is often insufficient to control mealybug outbreaks. In this presentation, we will use the long-tailed mealybug *Pseudococcus longispinus* as a model to investigate the factors determining the efficacy of mealybug parasitoids. First, we will describe the parasitoid complex of *P. longispinus* in Mediterranean persimmon, where this invasive mealybug has become a key pest. We found that the most abundant and widely distributed primary parasitoid species, *Anagyrus fusciventris,* can potentially control *P. longispinus* in Mediterranean persimmon, but parasitism is highly variable among orchards. We evaluated the effect of certain factors on the parasitoid's efficacy, including hyperparasitism, the presence of mutualistic ants, and habitat context. Although hyperparasitoids were abundant and parasitized the mealybug instars used by females of the main primary parasitoid, the population growth rate of the mealybug was not affected by hyperparasitism, suggesting that this factor is not responsible for the high mealybug infestation levels. Remarkably, the presence of mutualistic ants and habitat context affected mealybug parasitism and abundance. Various mediterranean ant species attended *P. longispinus*, decreasing its parasitism and increasing its abundance. On the other hand, the presence of non-crop habitats, both inter-row ground cover vegetation and surrounding semi-natural habitats, increased mealybug parasitism and reduced mealybug abundance. Our findings serve as a cornerstone for enhancing the control of *P. longispinus* through augmentative and conservation biological control strategies that improve parasitoid efficacy. Future research should assess other potential factors affecting mealybug parasitism, including insecticide usage and climate warming.

Session 8-O6 - Use and preservation of parasitoids in agriculture

Virome of the citrus mealybugs *Planococcus citri*, *Delottococcus aberiae* and their parasitoids: potential implications for biological control

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Viruses shape host-parasitoid interactions and, therefore, can affect biological control. While some parasitoid species require viral infections to parasitize and develop in their hosts, some viruses can alter the parasitism susceptibility of their herbivore hosts. Among the well-studied viruses in parasitoid-host interactions are DNA viruses, particularly polydnavirus, which play a crucial role in parasitism by suppressing the immune system of the herbivore host. However, not all parasitoid species carry these viruses. During the last decade, it has been evidenced that other unnoticed RNA viruses, which are ubiquitous in insects, can contribute to the failure or success of parasitism. The aim of this study was to: (i) describe the RNA virome of two mealybug species, important for Mediterranean citriculture: *Planococcus citri* and *Delottococcus aberiae*, their respective primary parasitoids: *Anagyrus vladimiri* and *A. aberiae*; and (ii) assess the influence of some of these viruses in parasitism. By high-throughput sequencing, we described 17 RNA viruses, including 14 new viral species. *Planococcus citri* and *D. aberiae* had three viruses in common whilst both parasitoid species shared three viral species. Interestingly, *A. aberiae* and *A. vladimiri* transmitted one and three different viruses respectively to their hosts through parasitism. Transcriptional profiling of the parasitized insects has contributed to the identification of viral species potentially involved in the parasitism process. Ongoing research is now directed toward unravelling the potential roles of these viruses in the intricate dynamics of mealybug-*Anagyrus* interactions.

Session 9-O1 - Biological control in a changing world!

How to control a regulated invasive pest in a sustainable way? The case of *Popillia japonica* in continental Europe

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Popillia japonica is an invasive pest to continental Europe since about ten years and has been declared a high priority quarantine pest in the European Union and associated countries. This status implies obligatory monitoring of the pest, and, most important, a forced implementation of control measures upon detection.

What seems straight forward on paper is especially tricky in the case of *P. japonica*. First, the broad host range of the invasive pest enables it to thrive in a wide range of crop and non-crop areas, and an area-wide treatment of such a patchy habitat with insecticides is simply impossible. Second, *P. japonica* adults have a long flight period of about two months, and peak flight period coincides with harvesting periods of many soft fruits. Control of *P. japonica* adults would therefore require multiple insecticide applications, and violate pre-harvest waiting periods.

We investigated the application of entomopathogenic fungi against *P. japonica* adults in an "attract-and-infest" approach. We use specific lure traps to attract beetles, infest them with fungal inoculum, and release them after inoculation. The system is very selective for the pest insect and therefore less harmful to non-targets. Released inoculated beetles aggregate with other beetles in the crop canopy and transmit the inoculum to their conspecifics. The dissemination of the inoculum is possible in virtually any environment, and leaves minimal residuals on plants or produce only. Moreover, exposure of fungal spores to drought stress, extreme temperatures and UV radiation can be kept to a minimum.

Preliminary results show that fungal spores are transmitted among *P. japonica* beetles, and kill the pest within days after release. While the trapping system still needs improvement, the concept of the "attract-and-infest" approach has been proved and may become an important means of application of microbial control agents in future.

Session 9-O2 - Biological control in a changing world!

Biocontrol initiatives for invasive weeds in the Pacific

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Invasive weeds are a serious problem for Pacific Island Countries and Territories (PICTs), threatening native biodiversity and ecosystem services, and impacting on health, wellbeing, and food security. Often, PICTS lack the necessary resources to effectively control weed invasions, and management challenges are likely to be exacerbated in the coming decades, as unwanted species continue to invade, and climate change intensifies the harmful impacts these weeds have. Responding to this urgent need for more on the ground action against invasive species, the Pacific Regional Invasive Species Management Support Service (PRISMSS) was formed by the Secretariat of the Pacific Regional Environment Programme (SPREP) in 2019. PRISMSS aims to provide required support to PICTS to strengthen in situ invasive species management. Manaaki Whenua – Landcare Research (MWLR) was invited by SPREP to join PRISMSS and lead a Natural Enemies – Natural Solutions programme for invasive weeds. This presentation provides highlights from a recently completed, highly successful, 5-year programme in the Cook Islands, and progress from an on-going 7-year project to tackle pasture weeds in Vanuatu. We also outline the new Restoring Island Resilience Project and work conducted under the Managing Invasive Species for Climate Change Adaptation in the Pacific (MISCCAP) programme, in which MWLR is working closely with SPREP and New Zealand's Department of Conservation, and related GEF-6 projects. Finally, key lessons learnt and future opportunities to support our Pacific neighbours are reflected upon.

Session 9-O3 - Biological control in a changing world!

Can cryptic sex enhance the performance of an asexual aphid parasitoid?

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Sexual reproduction has considerable genetic benefits, for instance it increases adaptive potential and helps to purge deleterious mutations. These benefits come at a cost however, because sexually reproducing females must produce male offspring their reproductive success is expected to be half that of an equivalent asexually reproducing female. Parasitoid wasps commonly used in biocontrol exhibit both sexual and asexual reproductive strategies, but do asexuals or sexuals make better biocontrol agents? While asexual biocontrol agents should in theory, be more efficient at controlling their host pests, in a changing world, where hosts can rapidly evolve resistance and environmental conditions can rapidly change, the adaptive potential that sex provides may become increasingly important. In this study I test whether rare facultative sex in a mostly asexual aphid parasitoid, *Lysiphlebus fabarum* represents the 'best of both worlds'. I predicted that facultative sex would result in higher recruitment of female offspring and increased fitness due to genetic diversity when compared to obligate sexual or asexual conspecifics. While facultative sex does result in complete production of daughters and genetically diverse offspring, this does not translate to improved fitness and higher parasitism. In fact, facultative sex was associated with high rates of reproductive failure compared to obligate sexual and asexual reproduction, possibly due to genetic slippage (the breaking up of alleles which work well together). The next step is to determine the extent to which these costs impact the parasitism rate over multiple generations and in environmental conditions that are relevant to biocontrol.

Session 9-O4 - Biological control in a changing world!

Pesticide-induced food and macronutrient limitation in beneficial carabid beetles in agroecosystems

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Pesticide usage is claimed as the main cause of insect declines. Pesticides can directly eradicate beneficial predatory beetles, but they are also exposed to indirect pesticide effects arising from reduced prey (as well as plant-based food) availability and quality in agroecosystems. The main aim of the current study was to investigate if higher food and macronutrient limitation levels in carabid beetles are related to conventional agricultural practices (especially pesticide usage).
Individuals of different carabid species were collected by hand from 8 conventional and 8 organic oat fields scattered around Tartu, Estonia (three times). In the laboratory beetles were served with three semi-artificial diets: lipid-rich, protein-rich, and sugar-rich. Consumption of each diet was evaluated after 24 hours (= test1). Afterwards, beetles were fed ad libitum for a week until full satiation. Then the procedure of test1 was repeated (= test2). The differences of consumed diets among two tests showed the level of food and macronutrient limitation in carabids within assemblages. Separately, pesticide residue analyses in beetle bodies were performed.
Seven different pesticides were detected in beetles from conventional fields. Several carabid beetle species weighted less in conventional than in organic fields. Double-test experiment revealed that carabids tended to be more food as well as sugar and lipid limited with the presence of neonicotinoid insecticide and less so in organic fields. Finally, beetles were less protein-limited in organic fields. We conclude that organic farming and reduced pesticide usage would improve beneficial carabid nutrition and fitness thus leading to higher efficiency in providing biocontrol service.

Session 10-O1 - Mechanism in conservation biological control

Pronematus ubiquitus: a multitasking mite for pest and disease control

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The tomato russet mites (*Aculops lycopersici*) and powdery mildew are two main bottlenecks in tomato cultivation for which no effective biocontrol solutions exist. Commercially available predatory mites come from a single family (the Phytoseiidae). These are usually a poor match for tomato plants as they are too big to navigate the glandular hairs (trichomes). To solve this issue we studied small mites from the superfamily Tydeoidea, in particular the species *Pronematus ubiquitus*. Being omnivorous, these mites can feed on small arthropods, pollen, fungi and plant sap. Due to this broad diet, the mites can be preventatively established using the pollen food supplement Nutrimite.

P. ubiquitous proved exceptionally effective in suppressing tomato russet mites. In addition, we noticed that plants inoculated with *P. ubiquitous* remained free of powdery mildew, while control plants in the same compartment suffered high mildew infestation. This makes *P. ubiquitous* the first reported example of an arthropod that concurrently controls a pest and a pathogen.

Powdery mildew is of course also a major problem in a range of other crops, including strawberries, where it affects both the leaves and the fruit. In commercial strawberry production, weekly fungicide treatments are required to control this pathogen. Our trials showed that in strawberries as well, *P. ubiquitous* can build up large populations on strawberry foliage, following a single introduction and biweekly feeding with pollen (Nutrimite). The mite provided better protection than conventional or IPM strategies. *P. ubiquitous* could be a real game-changer in biological crop protection.

Session 10-O2 - Mechanism in conservation biological control

The IOBC-NTRS Conservation Biological Control Working Group

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Conservation Biological Control (CBC) practices are closely related to the habitat management approach and are one of the main tools for the ecological management of pest arthropods. It is known that ecosystem biodiversity can provide many benefits to the agrosystem such as improved pollination, wildlife conservation, increased productivity, carbon sequestration, and pest suppression. However, given the complexity of trophic web interactions, this practice still faces challenges regarding its applicability in the field. Based on these ideas, a group of researchers working with these foci proposed the creation of a working group associated with the IOBC. The CBC Neotropical Working Group (CBC/WG) aims to evaluate and disseminate knowledge about research and results on Conservation Biological Control in Latin America. The emergence of the group's idea, in 2019 and its implementation, will be reported. Since the creation of the group, many activities have been developed, seeking to give greater visibility to the researchers and exchange of information between researchers from Latin America and the Caribbean. Also, lecture sessions were held at congresses in Brazil, Argentina, Colombia, and other countries, and participation in the last International Symposium on the Biological Control of Arthropods (ISBCA)(Virtually), 2022. An important action of the IOBC/NTRS has been the webinars, which take place monthly online, in which work from different groups, from the regional and other IOBC sessions, are presented. Several CBC/WG participants presented their work in the webinars and some examples will be shown. In this scientific session, some colleagues will present their work related to the CBC. One of the main goals of our group is to promote a research network on Conservation Biological Control and we know that, with each event participation, this network expands.

Session 10-O3 - Mechanism in conservation biological control

Elicitor based Attract and Reward strategy against *Dysaphis plantaginea* in apple orchards

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In order to ensure an efficient control of pests, habitat manipulation approaches combining various mechanisms, as Push-Pull and more recently Attract and Reward, have been developed. Such habitat manipulation could also have an impact on the whole trophic network, from the pest to third parties, and a precise evaluation of the impact of such approaches on the whole system is required. The rosy apple aphid, *Dysaphis plantaginea,* is a major pest of apple orchards, producing extensive damage early in spring, when natural enemies are scarce and floral resources are limiting. Moreover, this aphid is tended by ants which disrupt its control by natural enemies. We developed an original Attract and Reward strategy using plant defence elicitors to enhance both the production of Herbivore Induced Plant Volatiles (HIPV) by the apple tree and extrafloral nectar by faba bean, used as companion plants. Various plant defence stimulators were studied in the lab to enhance the production of extrafloral nectar by faba bean. Acibenzolar-S-methyl, a functional analogue of salicylic acid, known to enhance the production of HIPV by apple tree, as well as mechanical leaf injuries, were efficient elicitors to enhance the production of extrafloral nectar by faba bean. A sentinel plant approach was used in an orchard network to determine the efficiency of both attract and reward component, isolated and together. An exclusion factor was added to exclude ground dwelling predators and ants. While no effect has been observed when attract or reward components were tested alone, their combination increased significantly the biological control of the rosy apple aphid, mainly by syrphids, but only in early spring, when the floral resources are limiting, and when ants were excluded. These results emphasize the need to combine various levers, to deal with all the interacting protagonists and to focus on critical period when the conservation biological control actions should have the highest impact.

Session 10-O4 - Mechanism in conservation biological control

Accessibility, availability and nutritional value of native flowers from central Chile to *Mastrus ridens* (Hymenoptera: Ichneumonidae), a natural enemy of codling moth

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Habitat or vegetation management is one of the main strategies used at the field level in conservation biological control, and its objective is to provide natural enemies with complementary resources. Laboratory studies have shown that when parasitoids receive sugary food, their longevity and fecundity increase. In the field, the most common sugary foods are flower nectar and honeydew, but their accessibility, availability and nutritional value can vary between species. In this study we evaluated whether native plants from central Chile can provide sugar resources that benefit *Mastrus ridens* (Hymenoptera: Ichneumonidae). For this purpose, we also measured parasitoid head and flower morphology to determine nectar accessibility, and followed flower phenology to determine its availability. For nectar nutritional value, we determined female longevity when exposed to flowers of eight native species and nectar of seven native species, that belonged to five different families. We also exposed females to flowers of two non-native species (*Fagopyrum esculentum* and *Lobularia maritime*) commonly used, diluted honey (positive control), and water (negative control). We found that for three species effective nectar depth was too large, and the parasitoid cannot access it. Most species had flower at least partly during the activity period of the parasitoid. Regarding nutritional value, experiments with flowers showed that the greatest longevity was with honey (19.9 ± 1.0 days), then buckwheat (*F. esculentum*, 4.3 ± 0.7 days) and the native *Encelia canescens* (3.7 ± 0.6 days), all differing from water (2.4 ± 0.4 days). In experiments with nectar, the greatest longevity was with honey (15.9 ± 2.9 days), followed by the native *Andeimalva chilensis* (5.5 ± 1.7 days). The results suggest that *M. ridens* does not benefit significantly from the floral resources studied. We are currently analyzing the nectar composition to determine its nutritional value, and floral volatiles that could influence parasitoid attraction. This study highlights the importance of measuring the effects of floral resources on natural enemies before establishing habitat management at the field level. Funding FONDECYT 1221764

Session 10-O5 - Mechanism in conservation biological control

Milpa farming: fostering biological control in a traditional Mesoamerican agricultural system

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The Milpa, a traditional agricultural practice in Mesoamerica that in most cases involves the co-cultivation of beans, maize and squash plants, is renowned for its high level of natural pest control. This unique system provides an ideal setting to investigate the ecological interactions among plants and the associated arthropod community that are the basis for this robust and sustainable mixed-cropping strategy.
In a 2-year field study conducted in Oaxaca Mexico, we investigated the relationship between crop and arthropod diversity in the traditional milpa intercropping system. Using replicated, bicultures and tricultures of maize, beans, and squash in an agricultural field in Oaxaca, Mexico, we compared herbivore and natural enemy diversity throughout two consecutive field seasons. Our findings highlight that the milpa system promotes greater arthropod diversity in comparison to monocultures for both herbivores and natural enemies. This increase in arthropod diversity primarily stemmed from the individual impacts of each crop species, while synergistic effects, particularly evident within squash-maize bicultures, also contributed. Additionally, we discovered that crop diversity led to an increase in yield. These results are presented in light of the ongoing discussion regarding the utilization of intercropping systems in agriculture, emphasizing the importance of understanding how specific plant traits affect interactions among plants and their associated insects when considering crop combinations.

Session 10-O6 - Mechanism in conservation biological control

Conservation strategies applied in sugar cane in Colombia: a successful case

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The global increase in different forms of organic agriculture and sustainable production standards have highlighted environmentally friendly and easy-to-implement practices such as biological control for conservation. This practice seeks to increase the supply of resources available for functional biodiversity that controls pests, allowing the generation of benefits in terms of production and in terms of goods that can be perceived by communities that coexist in the agroecosystem. With this perspective, for several decades the sugar cane industry in Colombia has been implementing low environmental impact means, where biological control for conservation is a key step in pest management schemes. This practice has gained strength among farmers, who restore the natural vegetation present in riparian corridors and other uncultivated spaces adjacent to the crop, in order to improve the conditions and resources for parasitoids and predators that feed on important pests such as river borers. *Diatraea* group and the spittlebugs *Aeneolamia varia*. We show the progress made in determining the fauna of parasitoids and predators that provide benefits and the advantages of this form of control, added to the different results that we have had after its adoption.

Session 10-O7 - Mechanism in conservation biological control

Encouraging the adoption of conservation biocontrol by farmers and the public using beneficial habitat plots

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The increasing interest in sustainability by growers and the public has created a window of opportunity for encouraging the adoption of conservation biocontrol. As part of an initial 2017 project to investigate the use of habitat plots to encourage biological control in Christmas tree production, we evaluated methods of weed management, planting and timing and measured input and labor costs as well as bloom times and insects trapped. Having the demonstration plots, insect samples and collected information available, we held a series of open houses in 2021–2023 for the public to encourage them to understand the concept of habitat for beneficial arthropods, and to recognize the organisms themselves. The same information was used as the basis for a 2020–2023 project to evaluate beneficial habitat for biocontrol of insect pests on urban vegetable farms in New York City. Information gathered from all 3 audiences was gathered into a series of resources available on-line and in hard copy that have been distributed to diverse stakeholders in New York State and beyond. In this presentation, I will cover the results of the projects, the impact on the targeted audiences, and the resources developed.

Session 10-O8 - Mechanism in conservation biological control

Conservation of natural enemies provides satisfactory control of pear psyllids in Mediterranean pear orchards

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Cacopsylla pyri (Hemiptera: Psyllidae) is the main pest of pear orchards in Europe. Chemical control is not a sustainable strategy due to economic, environmental and consumer-demand reasons. However, the control of pear psyllids is still largely based on the use of insecticides. Research was carried out in southern Spain to determine the potential of natural enemies to control the pear psyllid. Two 1-ha orchards where insecticide treatments were reduced as much as possible, always avoiding the use of broad-spectrum products, were sampled over four years to determine the long-term population dynamics of pests and natural enemies. Then, another experiment was carried out to clarify the role of ants on the pear psyllid population dynamics and to establish psyllid density thresholds. Five intensity levels of insecticide spraying with and without ant exclusion were assayed in a completely randomized block design with three replicates in a 0.5-ha pear orchard. In the four-year experiment, the most abundant phytophages were aphids (*Aphis spiraecola, Aphis pomi* and *Aphis gossypii*) and *C. pyri*, which represented 51% and 48%, respectively. The abundance of psyllids greatly decreased in years three and four, while that of aphids increased in the last year. The most important predator was the ant *Lasius grandis* (75%) followed by spiders (11%) and the predatory mirid *Pilophorus gallicus* (10%). The abundance of ants increased along the four years and was highly correlated with that of aphids. In the second experiment, the abundance of psyllids decreased with the intensity of the treatments and greatly increased when ants were excluded. The incidence of russet on fruits was also strongly reduced in the presence of ants and no differences were observed between the high- and low- intensity of spraying. A satisfactory control of the pear psyllid is possible with the conservation of natural enemies, reducing the frequency of spraying and eliminating broad spectrum insecticides.

Session 10-O9 - Mechanism in conservation biological control

Weeds associated with rice crop (*Oryza sativa* L.), as a refuge of *Telenomus podisi* for the reduction of the population of *Oebalus insularis*: a conservative control in a tropical agroecosystem

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The presence of the complex of weeds recorded around of the rice cultivated areas may favor the conservation of *Telenomus podisi* Ashmead (Platygastridae), based on the high oviposition rate of *Oebalus insularis* (Stål) reported. Therefore, the objective of the present study was to determine the parasitism rate of *T. podisi* in eggs of *O. insularis*, recorded in each weed species found in the areas surrounding the rice crop. Therefore, 25 random samplings were carried out in the vicinity of the area cultivated with rice, at 96 days after sowing (d.a.s.), which correspond to the milky grain phase. The delimitation of the samples points of *O. insularis* eggs by weed species recorded was 1 m^2. Subsequently, the masses of *O. insularis* eggs removed from the leaves of the weeds with the help of a brush, which were transferred to the Entomology Laboratory of IDIAP, in Panama. The eggs of *O. insularis* were placed in Petri dishes, with paper towels moistened at the base, and duly labeled according to the species of weed registered and the phenological development phase of the crop. The collected eggs masses were kept in climate-controlled chambers regulated at 28°C temperature, 80% relative humidity and 12 hours of photophase. Evaluations were performed daily, considering the total number of eggs parasitized by *T. podisi* and the total number of eggs per mass, to determine the parasitism rate (%) per weed species. The weed *Echinochloa colona (*L.) Link, presented parasitism rates between 80 and 85%, at 96 (d.a.s.), it should be noted that both *E. colona* and rice (*O. sativa*) belong to the Poaceae family. The evidence presented facilitates the implementation of a conservative biological control program in Panama.

Session 11-O1 - Trends in commercial biological control

Genetics of pest control agents: to what extent do they matter?

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Regulation of commercially available macro-organisms for augmentative arthropod pest control safeguards the process of mass-release of reared (sometimes non-native) species into an (often new) area and potential impacts on ecology, society and the economy. In the past, such commercial products were mostly evaluated based on the origin (i.e. local presence/absence) and biological features of the species or population used. In some countries where such biocontrol has been taken up long ago, there is a recent tendency to restrict approvals of commercial products to locally occurring taxa. The argument is reducing risks of impact on genetic resources, local biodiversity and ecosystem services. To that end, the industry is increasingly being asked to provide information on the genetics of their products.
This trend will have a major impact on the biocontrol industry and associated stakeholders. It limits the range of taxa that can be used. It would require localized sourcing and rearing of natural enemies, therefore decentralizing activities, and reducing cost-effectiveness for the industry. That would in turn reduce affordability and competitiveness of biological products for growers compared to conventional plant protection products (pesticides). These limitations may hamper the growth of biocontrol, or even reduce possibilities for biocontrol locally, with corresponding risks for local biodiversity.
We here aim to open the discussion on this dilemma. We first present definitions of 'local' and 'non-native' in the biological sciences. We then discuss the relevance of geographic origin and genetic make-up for successful application of biocontrol and corresponding environmental safety. We address potential effects of releasing commercially reared taxa on (local) biodiversity and its genetic make-up, e.g. via interbreeding. We place this discussion in a context of the increased spread of (exotic) pest populations and the drive to reduce reliance on conventional pesticides.

Session 11-O2 - Trends in commercial biological control

Advancing commercial biological control in North America through advocacy and education

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Commercial biological control in North America is represented by the Association of Natural Biocontrol Producers (ANBP) with about 21 producers, 13 distributors, eight practitioners, and a few other contributors (scientists, regulators, students, etc.). They advocate for augmentative biological control primarily by very active person to person, internet, referral, tradeshow, and other forms of marketing. Consequently, at least 80% of the producers and distributors report a continuous increase in sales of natural enemies, mostly species of mites (12), predators (19), nematodes (12) and parasitoids (27). Greenhouse and open field vegetable and ornamental plant production are the major applications. Based on a 2019 survey of 54 universities in the U.S., 18 provided classroom education and training in biological control, with seven offering courses via distance. However, another 18 universities had discontinued their comprehensive courses. The remainder delivered biological control information within courses involving integrated pest management and sustainable agriculture. Advancement of biological control in the United States at a rate commensurate with its potential will require considerably more highly trained biological control practitioners.

Current trends in commercial biological control in North America

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The commercial augmentation biological control industry in North America continues to grow and change due to many factors. Opportunities and challenges will be discussed and will include how international production companies are changing natural enemy availability, how regulatory policies affect markets, how new crops and increased greenhouse and organic production is demanding more biocontrol solutions, and how the need for more applied research remains a critical foundation for future growth.

Session 11-O4 - Trends in commercial biological control

Macrobial regulation within Europe – a comparison

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Regulation of Invertebrate Biocontrol Agent (IBCA) products for use in agriculture has been a much discussed topic in the EU arena over several decades, including the 2011 Regulation of Biological Control Agents (REBECA) study and 2022 EU Commission study on the introduction, production, evaluation, marketing and use of IBCAs. The EU Council concluded that there was inadequate information to pursue harmonisation of the regulation at EU level at this time. The inclusion of the invertebrate biocontrol agents in the definition of biological control in the EU Commission proposal for the Sustainable Use Regulation (SUR) has raised the subject to the forefront.

Within Europe (EU member and non-member states) there are considerable differences in the level of regulation IBCAs face, ranging from no regulation to high levels of restriction, also upon the species contained in the product (co-formulants), to the product itself. If we include pollinators in the topic then the subject is even more complicated.

Many countries follow a similar procedure for approvals or registrations, several follow a pragmatic system based on the EPPO Phytosanitary Measures (PM) 6 guidelines on the Safe use of Biological Control and the EPPO Positive List, which works well for both safety in nature and provides maximum benefit to the users and suppliers. The IBMA supports regulation to ensure the highest quality products are brought to market and applied in the target crop(s) while ensuring environmental safety.

This presentation will discuss how the regulatory requirements of countries align or differ, what impact these have on both the producers/license holders and the effective integration of biocontrol at end user level, and the moves to harmonise these between countries.

Session 11-O5 - Trends in commercial biological control

Developments in new commercial biological control products and delivery methods

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The use of biological control agents (BCAs) is being adopted at a high rate in protected crops in North America. With that, there is an ever-expanding repertoire of species and techniques for optimizing their impact. Canada has been leading the charge with new biological control species for North America. What began as a miniature breeding unit for the predatory mite, *Neoseiulus cucumeris*, has evolved into a single plant treatment system for at least 5 species of predatory mites, particularly useful on high value crops. There is a wide array of mechanized delivery systems ranging from handheld to tractor or drone mounted. Building on growers' desire to feed the BCAs that they have purchased, a variety of foods and banker plant systems are being deployed to maintain purchased BCAs long-term.

Enhanced conservation biocontrol using commercial-scale hydrogel baiting strategies for sugar-feeding ants in California vineyards

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Vine mealybug, *Planococcus ficus*, is the most significant pest of grape production in California vineyards. Effective management requires a combination of chemical and biological controls, often augmented by mating disruption. Over the past few years, reductions in pesticides that can be used in vineyards have made it more difficult to control mealybugs, and have made it nearly impossible to control sugar-feeding ants. These ants protect vine mealybug from predators and parasitoids that would otherwise provide conservation biological control. Our research focused on ant management through an experimental method to apply liquid-based baits to the vineyard as a solid. This was accomplished by hydrating polyacrylamide crystals with water containing 25% sucrose (to simulate honeydew) and small amounts of a toxicant, and then applying baits with a traditional bait or fertilizer spreader at rates ranging from approximately 20 to 40 l/ha. Screening various toxicants identified thiamethoxam (conventional) and spinosad (organic) as two of the most effective toxicants when applied at rates of active ingredient per acre that are approximately 1–2% of the amount of active ingredient that can be applied to the foliage or through the drip system according to current labels. During the most recent studies in 2023, a series of two applications at approximately 3–4 week intervals in the spring can provide good to excellent control for a period of 2–3 months. Parallel studies conducted in wine grapes and citrus have shown similar efficacy on other sugar-feeding ant species, including Argentine ant, *Linepethima humile*. Data on the impacts of ant removal on parasitism rates of vine mealybug, and on subsequent fruit infestation levels at harvest, have documented reductions in damage of up to 40% compared to plots where ants were not controlled. Efforts are currently underway to secure the necessary permissions from regulatory agencies in California to allow hydrogel baiting technologies to be used commercially by grape and citrus growers throughout the state.

Session 11-O7 - Trends in commercial biological control

Biological control of the tobacco thrips *Thrips parvispinus* (Karny)

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The tobacco thrips *Thrips parvispinus* (Karny) is threatening greenhouse horticulture worldwide. We evaluated diverse predators. In a laboratory trial *Amblyseius swirskii*, *Amblydromalus limonicus*, *Transeius montdorensis* showed the capacity to kill eggs of *T. parvispinus* in sweet pepper leaf tissue. In leaf disc assays, gravid females of *A. swirskii*, *A. limonicus*, *Neoseiulus cucumeris* and *T. montdorensis,* all reproduced and consumed between 2.2 and 3.3 first larval stage of the pest per day. The phytoseiids' predation and oviposition rates seemed lower than those reported on *Frankliniella occidentalis* as prey. This hypothesis was confirmed for *A. swirskii* in a laboratory trial. In a greenhouse cage trial with infested sweet pepper plants, *A. swirskii*, *A. limonicus* and *N. cucumeris* established and reduced the pest significantly following three introductions (300 mites/2 plants). *A. swirskii* and *A. limonicus* reached a higher population level on sweet pepper than *N. cucumeris* and consequently achieved the best control. On potted plants of *Ficus elastica Robusta* establishment of predatory mites is usually marginal. More aggressive predators like the lacewing *Chrysoperla carnea* and the predatory thrips *Franklinothrips vespiformis* were tested in a cage trial and at a commercial *Ficus* greenhouse. All biological control agents tested in greenhouses reduced the pest, but could not control it totally. The number of applications of synthetic pesticides were lowered, but the use of synthetic insecticides remained necessary. Biocontrol strategies against *T. parvispinus* are discussed as the pest is becoming a real bottleneck to the development of biological control.

Session 11-O8 - Trends in commercial biological control

Development of *Bipolaris yamedae* into a potential bioherbicide against paddy weeds

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Chemical control has been intensively adopted against weed infestation in paddy fields globally. Over-reliance on chemical herbicides for rice weed control poses challanges to the environment, food safety, herbicide-resistance, etc. Biological control is an alternative approach to solve the problems in paddy weed control. The potential of *Bipolaris yamadae* as bioherbicide was evaluated by determining its efficacy to weed control and safety to crops, pathogenicity to paddy weeds, infection process, mass-production, formulation and weed control effects in field trials. Weed control spectrum tests showed that the bioherbicide demonstrated effecive control of 20 gramineous weeds including *Echinochloa* spp., *Setaria viridis*, *Leptochloa chinensis*, *Eleusine indica*, *Pseudosorghum zollingeri*, *Leptochloa panicea*, *Bromus catharticus,* etc. and some sedges and broad leaf weeds. The ED_{90} values of the strains on different weed species ranged from $5 \times 10^3 – 5 \times 105$ conidia ml^{-1}. The crop sensitivity tests showed that the fungus had intense safety to 77 crops of 27 families including rice, wheat, barley, corn, soybean, cotton, etc. The observation of infection and disease development processes showed that the fungus quickly caused necrotic lesion of inoculated weeds within 24 h. Mass-production and formulation technology were developed. Both pot and field trials of the product demonstrated higher than 70% effective control of main target weeds. It may be concluded that *B. yamadae* has great potential to develop into a bioherbicide against paddy weeds.

Key words: conidium; *Echinochloa*; mass-production; formulation; pathogenicity; host range

Session 11-O9 - Trends in commercial biological control

Biological control of invasive species using known natural enemies

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Invasive pests are a very important topic in biological control research. With increasing international trade and globalization invasive species keep being spread around the globe. Without appropriate control measures the invasive pest can be destructive to crops in the invaded areas. As initially there is little experience with the new pest, and the development of classical biological control takes time, broad spectrum chemical control often seems to be the best, or only, control solution in the first period following the invasion. However, we have data that show already available natural enemies may offer effective control of invasive species if they are used in the right way. When *Tuta absoluta* arrived in Europe in 2006 the already available mirid bugs provided efficient control. Recently *Thrips parvispinus* has spread through Europe and North America, and we show that a combination of *Orius* bugs with phytoseid mites can provide effective control. Currently several *Scirtothrips* species are arriving in Europe, and these we show can be controlled with phytoseid predatory mites as well. The biological control of invasive species may thus not always be that difficult if the available natural enemies can do the job.

Control strategy for the complete cycle of *Lasiodiplodia theobromae* in avocado through *Trichoderma* spp. formulation sprays on foliage and litter: results from Chile, Peru, and Mexico

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Wood diseases represent a major economic threat in avocado crop, causing direct loss to woody tissues and post-harvest effects on the fruit. The biological control of these diseases has introduced innovative strategies, allowing a shift from painting to spraying and providing control over the entire disease cycle. The objective of this study was to evaluate the impact of *Trichoderma* and *Bionectrias* spp. (Mamull®) formulation through sprays on pruning cuts and sources of *Lasiodiplodia the*obromae inoculum in avocado orchards in Chile, Perú, and Mexico. The results indicate significant control levels ($P < 0.01$) that are consistent across the different countries. In Chile, biological management achieved an 86.5% reduction, showing efficacy similar to chemical paste application (80%) and superior to chemical fungicide spraying (56.4%). Additionally, the application reduces fungal conidia production in the field (55.4%), thereby decreasing inoculum pressure and resulting in a 52% reduction in post-harvest rot. In Mexico, biological control achieved a 72.4% control, while chemical control reached 65.5%. In Perú, biological management achieved a 92.4% control, chemical paste application reached 74.5%, and chemical spraying achieved 64.7%. Spraying biocontrol fungus formulations achieves a level of control and logistical ease superior to chemical alternatives.

Session 12-O1 - Biocontrol of invasive alien grasses

Biocontrol of annual grasses associated with wildfire in North America

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Several annual grasses of Eurasian origin have become invasive in North America and are contributing to increases in wildfire frequency and magnitude causing great economic, ecological, and social destruction. Four species: cheatgrass (*Anisantha tectorum*), red brome (*A. rubens*), medusahead (*Taeniatherum caput-medusae*), and wiregrass (Ventenata dubia) are targets of an international classical biological control program led by USDA-ARS. To date, surveys in southeastern Europe and western Asia have revealed six candidate biocontrol agents on cheatgrass: a mite, a weevil, two gall midges, and two pathogens; and two candidate agents on medusahead: a mite and a gall wasp. Pre-release evaluations for all candidate agents are underway. The candidate agents collected from cheatgrass will be tested on its progeny species, red brome. Surveys of wiregrass have been limited to date and will focus on Central Europe.

Session 12-O2 - Biocontrol of invasive alien grasses

Exploring the potential of eriophyid mites in biological control of annual grasses

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Eriophyid mites are obligate plant feeders with high host specificity, efficacy, and long-lasting effects on their hosts, therefore, they possess many attributes that favour them as potential biological control agents of invasive plants. However, due to their microscopic size and the general lack of knowledge regarding their biology and behaviour, working with eriophyid mites may be particularly challenging. Moreover, some species may be extremely host-specific, often at the intraspecific level, and/or highly coevolved with their host as much as not to induce significant damage on the host, hence, resulting in ineffective biological control agents. *Aculodes altamurgiensis* and *A. marcelli* are two eriophyid mite species recently described from medusahead (*Taeniatherum caput-medusae*) and cheatgrass (*Bromus tectorum*), respectively. Both grasses are native to Eurasia and Mediterranean regions and are considered noxious and invasive weeds in much of western North America. Host specificity testing under open-field conditions to study the colonization rates of *A. altamurgiensis* and *A. marcelli* on different American populations of medusahead and cheatgrass, respectively, will be presented, together with field and laboratory observations performed to explore the potential impact of both mite species on their own hosts.

Session 12-O3 - Biocontrol of invasive alien grasses

Investigating the floral smut *Ustilago quitensis* as a potential biocontrol agent against pampas grass in New Zealand

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Pampas grass, a perennial grass indigenous to South America, has invaded various regions, including New Zealand, Australia, South Africa, the United States, and parts of Europe. In New Zealand, two Pampas grass species, *Cortaderia jubata* (Lem.) Stapf and *C. selloana* (Schult. & Schult.f.) Asch. & Graebn., can form dense stands that outcompete native plants. Surveys were conducted within its native range in 2012–2013 to identify potential biocontrol agents. The smut fungus *Ustilago quitensis* Lagerh. was found in Ecuador and later in Chile. It was brought to Manaaki Whenua – Landcare Research's plant pathogen containment facility in Auckland in 2017, where its life cycle is currently under study. On artificial media, teliospores generate haploid sporidia that can only infect plants when they fuse with sporidia of the opposite mating type. An attempted method to identify compatible smut mating types, involving combining two sporidial types on charcoal media, was tested but proved unsuccessful. Specific primers were designed to target the mating-type loci of *Ustilago quitensis*. This revealed the presence of four different mating types, suggesting that the life cycle *of Ustilago quitensis* is governed by two independent mating type loci, similar to *Ustilago maydis*. Three-year-old pampas seedlings were injected with a 0.5 ml spore suspension containing two different mating types and were harvested 20 months later. Due to the difficulty of inducing pampas plants to flower in controlled greenhouse conditions, a species-specific real-time PCR (TaqMan) assay was developed to detect *Ustilago quitensis* in plant tissues. This assay identified the smut fungus in the stem of the "inoculated" plants. Importantly, the smut was only found in plants that were inoculated with opposite mating types, confirming the efficacy of the inoculation method for enabling infection and the specificity of the PCRs designed for determining *Ustilago quitensis* mating types.

Session 12-O4 - Biocontrol of invasive alien grasses

Tri-trophic plant-herbivore-parasitoid assemblages and diet breadth across native and introduced grasses

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Interest in biological control of invasive grasses highlights the importance of ecological knowledge for effective management. This study explores the evolutionary ecology of insects associated with grasses in both native and introduced ranges, aiming to understand invasion processes and identify biological control opportunities. Despite established predictions about drivers of insect diet breadth across ecosystems, their applicability in regional grass assemblages is understudied. We tested the assumption that closely related host plants are preferentially targeted by specific insect herbivores, and that related parasitoids are more likely to attack more closely related herbivores with similar life histories. We collected 51 grass species in Kenya and Texas and reared out their insect associates. The insects were morphotyped, CO1 barcoded, and taxonomically identified. We used comparative phylogenetics, phenological data, and literature to infer trophic interactions. We also barcoded all grasses at the ITS locus to measure their phylogenetic similarities and extracted chemicals from the Texas grasses to quantify their chemical similarities. These data were correlated with insect herbivore assemblage similarities to indicate whether host phylogenetic or chemical similarities affected host usage. In this presentation, we reveal findings on regional patterns of herbivore and insect diet breadth. The results support the hypothesis that internally feeding grass herbivores, such as midges (Cecidomyiidae), demonstrate host specificity, positioning them as promising biological control candidates for invasive grasses. These findings also inform predictions about the likelihood that native parasitoids can host shift to biological control candidates and enhance understanding of which plant characteristics influence herbivore host usage patterns. These insights are integral to ongoing assessments for Guinea grass (*Megathyrsis maximus*) biological control candidates.

Session 12-O5 - Biocontrol of invasive alien grasses

Biological control of invasive African grasses: progress and prospects

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Historically, grasses have been avoided as targets for biological control due to concerns over a lack of host specificity and potential to inflict damage by possible control agents. However, recent work has demonstrated that insects and fungal pathogens can be suitable and highly effective biological control agents. Since 2017, the Centre for Biological Control at Rhodes University in South Africa has initiated several biological control programmes against native African grasses that have become invasive in either the USA or Australia. In this paper, we highlight the progress made towards developing biological control programmes against three key invasive grasses; weedy *Sporobolus* spp. (Giant rat's tail grass) and *Eragrostis curvula* (African lovegrass) in Australia, and *Megathyrus maximus* (Guineagrass) in the USA. We summarise the native-range studies completed for all three species, including describing the natural enemy communities, field host-range surveys, no-choice host-range testing and pre-release efficacy surveys. Across all three programmes, nine possible biological control agents have been identified and assessed to date. Thereafter, we discuss the challenges we encountered during these programmes and measures taken to overcome these issues. Lastly, we provide updates on the possible biological control options available for a range of other invasive African grasses (e.g. *Andropogon gayanus* [Gamba grass], *Hyparrhenia hirta* [Coolataai grass]). Developing biological control programmes for invasive grasses is not without its challenges, but our work has shown that grasses can be suitable targets for biological control.

Session 13-O1 - Biocontrol and climate change

Climate change, plant defenses, and consequences for biological control

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Climate change is expected to have multifaceted impacts on the physiology of both plants and pest insects which in turn will affect the success of biocontrol agents. Here we explore the distinct impacts of key climate change factors associated with atmospheric change —elevated CO_2, O_3, UV light, and temperature on plant secondary chemistry, a pivotal element in plant defense against insect herbivory. The influence of climate change on secondary chemicals is plant species-specific, contingent on the nature of the chemical compounds involved. While plant responses to these factors display considerable variability, there are discernible patterns in how different environmental stressors elicit particular chemical responses. However, we know little regarding how these factors directly and indirectly affect insect reproductive performance, behavior, herbivory rates, and susceptibility to natural enemy attacks. This knowledge is paramount for gaining understanding of biological control programs of plant and insect pests will be affected by climate change.

Session 13-O2 - Biocontrol and climate change

Biocontrol, climate change and population dynamics: Why is an increase of pest outbreaks and plant diseases transmitted by vectors expected following climate changes?

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Climate change has profoundly affected insect pests and their natural enemies, challenging biocontrol functioning and plant and food security worldwide. Climate change will contribute to new pest outbreaks and insect vector-borne plant disease epidemics by altering insect distribution and phenology, causing spatial-temporal mismatches of insect pests and their natural enemies. Generally, the impacts of climate change on distribution and phenology of species at higher trophic levels (predators/parasitoids) is expected to be greater than that at lower trophic levels (insect herbivores), which is likely to hinder biocontrol efficacy and thereby causing pest outbreaks and plant disease epidemics. On the one hand, climate change can directly eliminate or reduce abiotic constraints of insect pests, or indirectly alter interacting species profiting insect pests outweighing their natural enemies, thereby facilitating greater range expansion of insect pests. On the other hand, climate change has modified key phenological events such as spring emergence and overwintering diapause of insects and is causing phenological shifts, leading to changes in insect voltinism (generations per year) and abundance. Since the direction and magnitude of phenological shifts are taxon- and species-specific, interacting species may differ in their phenological responses to climate change, resulting in mismatched phenological synchrony. Phenological mismatches between interacting species can alter the structure and dynamics of insect communities, which can weaken the ecosystem functioning of biological control. Moreover, insect pests are expected to present better plastic and/or evolutionary adaptation capacities due to their shorter generation time and greater niche breadth than their natural enemies. All of these can scale up to facilitate higher potential of pest outbreaks and disease epidemics under climate change.

Session 13-O3 - Biocontrol and climate change

Thermal performance drifts between egg-parasitoid and its host may threaten the efficacy of biological control of a global pest

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The biological control of insect pests in agroecosystems is central to integrated pest management. For pests that are highly damaging at larval stages, egg parasitoids prevent hatching and thus inhibit pest development to the economically damaging stages. *Telenomus remus* (Nixon) is the main egg parasitoid of fall armyworm (FAW), *Spodoptera frugiperda* (J.E Smith) in its native range, with great potential for its classical biological control in invaded regions. However, host-parasitoid basal and plastic thermal responses necessary for adaptation in different geographies is unknown. Using established methods, this study compared thermal responses of *T. remus* versus FAW to low (18℃) and high (32℃) temperature acclimation through measuring critical thermal limits (CTLs) and other ecological traits. We hypothesized similar basal tolerance limits and plasticity culminating into possible overlapping thermal performance based on the upper and lower trophic level co-evolutionary theory. Our results showed marginal but significant increase in upper critical thermal limits (CT_{max}) following 32℃ acclimation and a decrease in the same trait after 18℃ acclimations. Heat acclimation (32℃) on the other hand significantly reduced *T. remus* cold tolerance (higher CT_{min}) whereas cold acclimation did not. Hatchability of FAW eggs dropped from 77.0 to 67.6% when exposed to similar heat acclimation and dropped even further, thus, from 77.0 to 56.2% after cold acclimation. These results show that ecological performance of egg-parasitoid *T. remus* may be compromised by prolonged events of both heat and cold stress, along with the target host egg life stage. This points to a potential drift between *T. remus* - FAW thermal performance that may manifest as temporal and/or geographical asynchrony. This information is important for identifying suitable *T. remus* release areas and for incorporation of suitable acclimations in mass rearing protocols for future efficacious biological control.

Session 13-O4 - Biocontrol and climate change

Effects of CO_2 and heatwaves on trophic interactions mediating biological control systems

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Climate change is one of the most significant challenges facing natural and productive systems. Although our understanding of how productive systems, especially plants and herbivores, will respond to climate change has advanced significantly recently, the effects on tri-trophic systems involving plant-insect herbivores and natural enemies have rarely been investigated.

Elevated CO_2 concentrations have increased since the preindustrial era. They are predicted to almost double by the century's end, from >411 ppm to >700 ppm, leading to an increase in the average global temperature of >2.2°C. In contrast, heat waves (periods when maximum temperatures are above seasonal norms by 5°C for at least five consecutive days), are increasing in frequency and intensity with climate change, and now predicted to have more dramatic biological effects in natural/productive systems than mean temperature increases. Higher trophic levels, e.g., predators and parasitoids, are predicted to be more strongly affected than herbivores because they may have smaller thermal windows and altered ecological interactions with lower trophic levels.

We present the results of our past and ongoing research testing the effects of (a) elevated (800 ppm) versus ambient CO_2 (400 ppm) on chemically mediated interactions in a model system of *Brassica* plants, the specialist aphid *Brevicoryne brassicae* and its endoparasitoid *Diaeretiella rapae*; and (b) heatwaves of varying intensity (36–40°C) and duration (one 5-day consecutive heatwave vs two 5-day consecutive heatwave events with a 3-day normal-day event in between heatwaves) on the fitness and reproductive success of the egg parasitoid, *Trissolcus japonicus* reared on eggs of the brown marmorated stink bug (*Halyomorpha halys*). We discuss the implications of our results on the stability and functionality of trophic interactions mediating biological control systems.

Session 13-O5 - Biocontrol and climate change

Biological control systems and climate change

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In agroecosystems, one of the major ecosystem services is biological control of crop pests. This service, supported by biodiversity, has been significantly altered by global environmental changes. The term biological control is generally used to define any suppression of an organism harmful to humans (pests, such as insects, mites, weeds and plant diseases) by another living organism, called Biological Control Agent (BCA), which includes predators, parasitoids, pathogens, fungi, bacteria, viruses … Biological control involves an active human management role and can be an important component of Integrated Pest Management (IPM) programs. There are different basic strategies for biological pest control: (i) classical, where a natural enemy of a pest is introduced into its new range; (ii) augmentation, in which large numbers of natural enemies are released for rapid pest control; (iii) biological control by conservation, involving habitat management to favor natural enemy populations and disadvantage pest populations. This communication will present the main conclusions of a book to be published, which main objective is to synthetize the effects (positive or negative) of climate change on the different methods of biocontrol. It aims to provide the keys to understanding the impact of climate change on the different Biocontrol methods, in order to be able to adapt them to new environmental conditions. Indeed, most studies about climate change are focused on the impact of climate change on individual species, whereas biological control methods involve interactions between species at different trophic levels and then the necessity to develop an understanding at a large scale. Climate change is a challenge that will require the development of flexible strategies capable of responding to changes in pest distribution and/or food web structure.

Session 14-O1 - Raising awareness for action: Country perspective

Public-private initiatives to reinforce the research and increase the use of biological control in Brazil – SPARCBio case study

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SPARCBio (São Paulo Advanced Research Center for Biological Control) is a partnership between FAPESP (Foundation to Support Research in the State of São Paulo), University of São Paulo and Koppert (Dutch company, also based in Brazil). This is a long-term research Project (10 years) which the main objective is the development of a biological control model for tropical regions, especially for Brazil where it is very usual to release natural enemies in "Open Fields". The Center is especially set on macro, micro-organisms and semiochemicals. SPARCBio highlights the dissemination of knowledge for changing the "farmer culture" focused on agrochemicals in Brazil. It is going to have its own organizational structure, as well as the support of an international committee, with a Director from Brazil (J.R.P. Parra), Professor at USP/ESALQ. The Center is going to rely on the participation of researchers and specialists from different national and international Institutions, in different lines of research: prospection of new Biological Control agents in different regions of Brazil; developing new technologies and generating knowledge for Integrated Pest Management (IPM). Ultimately, the University will earn from royalties, the government from taxes on products that may be developed, and the company from the development of new products and technology applied on Brazilian conditions. We will not be known as technology replicators anymore, but generators and disseminators of our own technology instead.

São Paulo Advanced Research Center in Biological Control (SPARCBIO)-FAPESP-Koppert, process: 2018/02317-5.

Session 14-O2 - Raising awareness for action: Country perspective

Promoting biological control leads to improved implementation and long-term sustainability?

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In South Africa, classical weed biological control remains underutilized despite the success of numerous well-documented programmes. Over the past decade, the number of individuals employed to execute biological control outside formal research facilities has declined. Consequently, the responsibility of promoting awareness and carrying out biological control implementation primarily falls on the researchers and students associated with each programme. Several research groups have successfully developed and implemented awareness campaigns resulting in involved community members contributing towards the programme. We identified the most successful programmes in South Africa based on factors such as the number of agents released and/or release events, the number of press releases, and the estimated number of community members engaged. We then examined these programmes to identify the characteristics contributing to their success. Common elements included adequate funding, research champions, charismatic weeds, and iconic or economically important sites of invasion, were recognised as important. It showed that awareness campaigns have resulted in higher amount of agents being reared and released by community members, additional invasions reported, post release evaluations conducted and additional finances received contributing to the biological control programmes. It is concluded that if Government support for biological control in South Africa remains uncertain, communities will become more important in the effective implementation and sustainability of biological control making invasive species and biological control awareness programmes fundamental to long-term biological control success.

Session 14-O3 - Raising awareness for action: Country perspective

Collaboration platforms and public-private initiatives favouring the uptake of biological control – case studies from Latin America

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The introduction and establishment of invasive species represent a challenge for agricultural production in Latin America and the Caribbean and, in most cases requires a regional approach for effective control. Biological Control is considered an important management strategy in the context of Integrated Pest Management. The high biodiversity characteristic of the Neotropical region results in the provision of natural enemies, which favours the establishment of Biological Control programs in the region. Despite this, public-private initiatives are crucial to ensure the uptake of biological control at the field level. The effectiveness of biological control will depend on the farmer´s familiarization with the mode of action and technology of application of the bioproducts. In this context, the establishment of collaborative platforms is very important to enable better communication and collaboration among key actors, such as researchers, extensionists, regulators, and the private sector, among others, and ensure a proper transfer of technology to farmers. Plantwise is a global programme coordinated by CABI. Since its launch in 2011, CABI's Plantwise programme has been introduced to 34 countries in Africa, Asia, and the Americas. The aim was to increase food security and improve rural livelihoods by reducing crop losses. Working in close partnership with over 170 in-country partners, Plantwise strengthened national plant health systems from within, enabling countries to provide farmers with the knowledge they need to produce more sustainably. In this talk, case studies will be presented, highlighting the contribution of collaborative platforms at the national, regional, and international level on the update of biological control for the sustainable management of invasive species in Latin America and the Caribbean.

Session 14-O4 - Raising awareness for action: Country perspective

Digital support tools : catalysing the uptake of bioprotection products through technological interventions

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Innovations in Biological Control have seen tremendous progress with time, though there are still major gaps in its utilization at the farm level. This can be attributed not only to the lack of availability of quality products but also to related information. With the advancement of technology underpinning the optimal use of bio protection products (BPP), digital support tools (DST) to disseminate knowledge and make decisions on their use can be a viable option. With DST, we explore the possibilities of reaching out to beneficiaries with information on nationally endorsed products mitigating the possibility of the use of spurious BPP. However, regular use of such DST is also dependent upon the users' knowledge of the selection, and application of BPP helping them to evaluate BPP performance in the field. A cost-effective way is to disseminate this knowledge through digital learning modules. More awareness would build the confidence of farmers in using the trusted BPP. Uptake of DST in biocontrol is a challenge and needs tremendous effort and a prospective promotional strategy. Sustainable use of an app is dependent on structuring it through the participatory approach of relevant stakeholders, the proven and tested content, robust backend support, and adequate internet speed. This is evident through a consistent userbase with considerable engagement while the app is in use. In developing countries, linguistic constraints, lack of supporting internet networks, and high cost of digital devices are some obvious impediments. The gender divide on the use of digital tools leads to low awareness of biocontrol amongst women farmers. In this study, we explore and evaluate the different mechanisms to reach out to the stakeholders especially agricultural service providers with such DST. We conclude that in-country promotions through governmental and non-governmental bodies, universities, corporates mandated for responsible farming support this purpose in a very promising manner.

Session 14-O5 - Raising awareness for action: Country perspective

Resolving conflict situations when using biological control against economically-useful invasive tree species

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The introduction of weed biological control agents may be delayed, or even prohibited, where the target plant species also has beneficial attributes. Usually these situations arise when biological control is being considered against invasive tree species which are valued as economic resources. Here we review three taxa that created conflict of interests situations including: *Acacia mearnsii*, European Pine, and *Prosopis* species. These invasive trees are recognized as some of the most environmentally harmful in South Africa. However, they also offer economic advantages which have created concerns about using biological control efforts against them. For two of the taxa the conflicts have been resolved; permission has been granted to release two biological control agents against *A. mearnsii* resulting in a substantial impact against the tree; while five biological control agents have been released against *Prosopis* with a number of additional agents under consideration. Despite biological control being considered for over two decades as a management option for wilding European pines, no agents have yet been cleared for release. Here we consider the history of the three programmes trying to identify key events leading to conflict resolution or lack thereof. We conclude that communication and cost-benefit analyses are essential components to resolving conflicts. However, they alone do not guarantee success. Persistence by researchers, prior successful conflict resolutions, changes in invasive status of target plant and agent selection may contribute to garnering support from all sides for releasing agents.

Session 14-O6 - Raising awareness for action: Country perspective

Development and technological transfer model of bioinputs based on endophytic microorganisms

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The world is under a rapidly changing climate regime, as a result of the generation of greenhouse gases, farmers face frequent and intense severe meteorological phenomena, affecting their production, in addition to facilitating the appearance of new and more aggressive pests and diseases. Faced with this worrying and complex scenario, moving quickly towards more resilient agricultural production systems where beneficial microorganisms are great allies is essential. Given the above, the INIA, through the National Center for Bioinputs (CeNBI), designed and implemented a model for the commercial development and transfer of bioinputs based on endophytic fungi called Endomix®. This model considered eight stages, which began with the exploration of around 150 candidates (fungal strains), the performance of preliminary tests of endophytic colonization, the effectiveness of its biocontrol action and growth promotion, and testing the potential of industrial scaling of the candidates which reduced the initial number to 20 strains. After evaluation at the laboratory and field level, and confirming its scaling potential, two strains of *Beauveria* spp. were selected. which constituted the product Endomix B1, which, together with increasing the resistance of plants against pathogens such as *Botrytis cinerea* and *Neofusicoccum* spp., promotes plant growth of species such as tomatoes and blueberries. After nine years of R&D Endomix B1 is in the national and international market (TRL 9), being the only product based on endophytic fungi, which validates the methodology developed at CeNBI.

Session 15-O1 - Improving biological control traits

Applications of life history theory in biological control

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Insects used in biological control encompass a diverse range of life history traits, many of which may be correlated or arranged in "suites" of characters. Despite the idealized notion that there is a specific set of life history characteristics that make an effective biological control agent, the variation in target pests, environmental contexts, and selection process result in a range of effective life history strategies. Biological control agents undergo both intentional selection during evaluation and unintentional selection through collection and rearing procedures that can shape the resulting life history traits of released biological control agents. Applications of life history theory can determine which life history strategies are effective in different environmental contexts and even the ways that biological control practices could be modified to support optimal life history traits. This presentation will discuss the current applications of life history theory to biological control practices including the selection of traits from among interspecific versus intraspecific variation, optimal traits among different environmental contexts, and environmental management. In evaluating biological control agents, we suggest focusing on 'suites' or axes of traits rather than characterizing individual traits for optimal performance within a given environmental context and pest system.

Session 15-O2 - Improving biological control traits

Trait selection in biocontrol agents - a review

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The performance of biocontrol agents may be improved by artificial selection for specific traits. Although arthropods are expected to respond to selection like traditional livestock, there is not a sizable history of improving biocontrol agents via artificial selection. There are a number of open questions regarding the prospects of artificial selection of biocontrol traits: (i) which traits should be selected? (ii) what is the genetic architecture of the desired traits and does this knowledge facilitate trait selection? (iii) is there sufficient genetic variation to select traits? (iv) are key traits heritable? (v) how fast do traits respond to selection? (vi) to what extent are there trade-offs between selected traits? and (vii) is effect size of trait selection large enough to significantly impact biocontrol success? As many traits may relate to overall fitness and behaviour they may have a polygenic basis with extensive epistasis and be subject to environmental conditions. They may also undergo inadvertent changes during long term laboratory maintenance and under mass rearing conditions (domestication effects). I will try to answer these questions by reviewing existing literature on trait selection in biocontrol agents. I will identify major gaps in our knowledge and understanding of trait selection in biocontrol agents and make recommendations for improvement of biological control programmes. The results of this review will be published in a special issue of Entomologia Experimentalis et Applicata on Trait Selection in Production Insects.

Session 15-O3 - Improving biological control traits

Biological control potential of a laboratory selected generalist parasitoid versus a co-evolved specialist parasitoid against the invasive *Drosophila suzukii*

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A few generations of laboratory selection can increase the developmental success of native parasitoids on invasive targets. However, it is unknown what the biocontrol potential of laboratory selected generalist native parasitoids may be compared to co-evolved specialists that are typically introduced for biological control of invasive species. We compared the parasitism rate of laboratory selected (adapted) and non-adapted populations of the generalist native parasitoid *Trichopria drosophilae* and the recently approved biocontrol agent *Ganaspis brasiliensis* to parasitize the invasive fly, *Drosophila suzukii*. More adult parasitoids emerged in each fruit type of the adapted compared to the non-adapted population of *T. drosophilae*. *Drosophila suzukii* emergence rates were reduced on average by 85% by the adapted *T. drosophilae* population indicating that the artificial rearing conditions did not significantly impair the ability of parasitoids to locate and attack hosts in natural hosts. The specialist *G. brasiliensis* had higher adult emergence than the adapted population of *T. drosophilae*, however, both parasitoid species were able to reduce *D. suzukii* populations to the same extent. These results show that despite the lower developmental success of the laboratory selected *T. drosophilae* they killed the same proportion of *D. suzukii* as *G. brasiliensis* when host choice was restricted. In nature, where host choices are available specialist and generalist parasitoids will be unlikely to exhibit the same biocontrol potential. However, laboratory selection of native natural enemies may be an approach worthy of further exploration given the significant reduction in new classical biological control approvals and introductions in North America and around the world.

Session 15-O4 - Improving biological control traits

How hard is it to improve a biocontrol trait? A case of parasitoid host specificity

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Being able to improve a trait for biological control success is contingent on numerous factors. Chief among these are that the trait has a strong enough genetic basis (heritability) to be selected for, and that the base population has enough genetic variation to conduct selection. We conducted a systematic review to determine how much is known about heritability and genetic variation of key traits in arthropod biological control agents. Screening of 2,927 relevant papers returned surprisingly little data, with only 69 having any measure of heritability or genetic variation. The existing heritability measures for fitness and field performance are generally (but not universally) low. This highlights the need for more studies collecting data fundamental to biocontrol trait selection. One important biocontrol trait potentially well suited for selection is host specificity or preference. Host specificity defines whether parasitoids are generalist or specialist in regards to the host species they use. In biocontrol it determines both field efficacy and risk of non-target effects. We use the parasitoid genus *Nasonia* to explore host specificity. Generalist and specialist *Nasonia* spp. can be interbred, the gene region controlling host specificity is known, and the trait is additive, specialist dominant. We give an overview on how this model has been used to explore natal host effect on host preference, host training and cue memory retention, breeding host specificity into lines, and delineating the genetic architecture of host specificity. This gives a multifaceted view on how (or if) a critical biocontrol trait can be improved through diverse approaches.

Session 15-O5 - Improving biological control traits

Molecular, taxonomic and behavioral characterization of house fly parasitoids in northern Italy

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Spalangia sp., *Muscidifurax* sp., and *Nasonia* sp. are frequently used worldwide as pupal parasitoids of *Musca domestica* for biocontrol purposes. However, in Italy, there is a lack of knowledge regarding the molecular characterization and distribution of natural populations of these parasitoids. Therefore, dairy farms mainly rely on commercial populations for biocontrol purposes. The aim of this study was to investigate and characterize the populations of housefly pupal parasitoids from conventional and organic dairy farms in Emilia Romagna (northern Italy) using molecular, taxonomic and behavioral approaches. The COI gene was analyzed for each species and haplotype based on provenance. Two populations of *M. zaraptor* were identified in both the organic and conventional farms. *Spalangia cameroni* was found to be present in one of the conventional farms, although it had never been intentionally released. *Nasonia vitripennis* was identified by taxonomic analysis and was obtained from a private Italian company. The study tested the behavior of *M. zaraptor* haplotypes 'a' and 'b'*, Spalangia cameroni*, and *Nasonia vitripennis*. For each species and population, groups of single mated females were provided with 10 housefly pupae each. Their parasitization activities were recorded for 4 hours. Differences between species and populations were observed for some parasitization activities, such as acceptance latency, drumming activity and number of unsuccessful parasitizations. The identification and characterization of the species and populations present in this area of northern Italy could contribute to the development of specific and targeted biological programs for farms. This can be achieved by using parasitoid species that do not compete, thus maximizing their effectiveness.

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Session 15-O6 - Improving biological control traits

Classical biological control of the emerald ash borer, an invasive forest pest of North America: challenges, management, and assessment of success

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Classical biological control has proven to be an effective measure to control and decrease the population of invasive species. Nevertheless, this approach comes with its own challenges and failures. Some of these include identifying appropriate, effective, and specialized enemies from the native range, testing their host range in quarantine, massive reproduction, release, establishment of the biocontrol agent in the environment, and finally evaluating its effectiveness at controlling the pest under field conditions. An invasive forest pest like the emerald ash borer (EAB) that attacks ash trees and arrived in North America more than 25 years ago is a perfect example of these challenges. Four parasitoid wasps have been released in the last 15 years in the United States and Canada as biocontrol agents with different levels of success at establishing and controlling EAB populations. Under temperate conditions and with a forest pest, the capacity of the wasps to synchronize their foraging period to that of the susceptible life stages of their host is one of the most important challenges. In Maryland, USA, we compared two geographical areas through monthly debarking of ash trees, where the life stages of EAB were matched with the foraging timing of wasps. We found differences between EAB phenology and the availability of susceptible larvae present throughout the season. High elevations showed a semivoltine life cycle, while univoltines were found at low elevations. This not only allows us to understand if there is a synchrony between the host and its natural enemies but can also be used to determine the best release period for ongoing introductions of parasitoid wasps and its dependence on elevation and climate. The collective effort and partnership with local authorities have made the management of information about the releases and recoveries of these agents an effective tool to assess the success of this biocontrol program and make predictions on ash health and recovery.

Session 15-O7 - Improving biological control traits

Ecological functions and intraspecific variability of *Trichoderma* sesquiterpenes and other volatiles

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Fungi belonging to the genus *Trichoderma* are prolific producers of volatile organic compounds (VOCs), which play a pivotal role in various ecological interactions. In the rhizosphere, *Trichoderma* seems to rely on VOC emission to outcompete plant pathogens rapidly. Variations in VOC profiles among *Trichoderma* isolates can influence their efficacy against pathogens and invertebrates. Conversely, VOCs may serve as foraging cues for fungivores like Collembola, potentially disrupting fungal competition dynamics by selectively grazing on hyphae.

We investigated 59 isolates of *Trichoderma* sp. "*atroviride B*," revealing substantial intraspecific variation in volatile profiles and fungistatic activity against *Rhizoctonia solani*. Notably, we observed a direct correlation between VOC abundance and bioactivity against the phytopathogen. Furthermore, we explored the ecological significance of sesquiterpenes, a prevalent group of *Trichoderma* volatiles, by generating a sesquiterpene-deficient mutant of *Trichoderma virens*. Choice experiments with Collembola demonstrated a preference for the mutant strain. The results suggest that sesquiterpenes play an important role in fungal defense as repellents, but not as deterrents or toxins, against fungivorous Collembola.

Additionally, both wild type and mutant strains exhibited negative effects on above-ground feeding caterpillars (*Helicoverpa armigera*) when colonizing maize roots, as indicated by bioassays. Our findings shed light on the multifaceted ecological roles of *Trichoderma* VOCs, underscoring their importance in the development of biocontrol strategies.

First report of *Brachymeria* spp. (Hymenoptera: Chalcididae) as a hyperparasitoid on *Charops bicolor* Szepligeti (Hymenoptera: Ichneumonidae) a larval parasitoid of *Spodoptera frugiperda* (J.E. Smith)

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We focus on the potential impact of natural enemies especially the parasitoids of fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), in Southern Rajasthan. A field collection of FAW egg masses and larvae was carried out during the Kharif season, 2023 in the maize growing area of the Udaipur region of Rajasthan, India. We sampled larvae and egg masses of fall armyworm and natural enemies and reared them in laboratory conditions. After seven days of observation, the parasitoid grubs moved out and formed a cocoon with a characteristic marking of black and white. The parasitoids emerged from a few pupae after 7 to 8 days of observation. The emerged adults of parasitoids were identified as *Charops bicolor* Szepligeti (Hymenoptera: Ichneumonidae) based on morphological and molecular characterization (Accession numberPP237211). A few days later, another black-colored hymenopteran emerged from the cocoon of *C. bicolor*which was identified as *Brachymeria* spp. (Hymenoptera: Chalcididae) based on morphological and molecular characterization (Accession number PP254242). The study confirms that *Brachymeria* spp. is the solitary hyperparasitoid of *Charops bicolor*, a larval parasitoid of *S. frugiperda* for the first time in Southern Rajasthan India. To the best of our knowledge, present study is the first record of chalcid hyperparasitoid *Brachymeria* spp. on the parasitoid, *C. bicolor*. *Brachymeria* spp. can disrupt biological pest control by suppressing the population of their parasitoid host *Charops* leading to pest outbreak.

Session 16-O2 - Biodiversity-based pest management practices

Multifunctional Margins for enhancing biodiversity in agroecosystems

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Promoting biodiversity in croplands is becoming a common practice in sustainable agriculture schemes. Incorporating Multifunctional Margins (MM) with dense plant arrays and a wide variety of families and species is a management strategy that has the potential to impact the agriculture practice beyond pest control and pollination. The preliminary results of an essay conducted in a melon crop farm in northwestern Costa Rica are presented. The main objective: to assess the impact of MM on beneficial insect diversity in melon crop. The essay was carried out in an experimental plot containing a control margin (with weeds and windbreak grass) and a multifunctional margin (with 26 selected plant species; area: 900 m^2). The establishment, development and phenology of the MM plants were recorded. Three samplings of beneficial insects were carried out in both margins, using yellow pan traps, sweep net and hand collecting. The planting was carried out in December 2022, and the insect sampling in July and September, 2023, and January 2024. The results indicate that MM has a positive effect on beneficial insect populations: the effect size for each group was 1.78 times (95% CI: 1.13–2.88) more parasitoids, 2.26 times (95% CI: 0.91–6.31) more predators and 8.18 times (95% CI: 3.11–39.21) more pollinators in the MM, compared to the control margin. 50 native bee species associated with the floristic resources (pollen and nectar) of the MM were recorded. The importance of biodiversity associated with the MM and the ecological networks between the crop and melliferous plants, as well as the challenges, plant selection criteria and learning lessons from the establishment of MM will be discussed.

Session 16-O3 - Biodiversity-based pest management practices

Practical considerations for the establishment of habitat islands for natural enemies – the case of oil palm in Malaysia

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Habitat management with local plants can provide resources for predators and parasitoids. Forty-five publications have demonstrated that diversified crops have more natural enemies, fewer pests, and less crop damage than crops with fewer associated plant species providing shelter, nectar, prey/hosts, and pollen for beneficial insects. The inclusion of non-crop habitat increases natural enemy populations, improves predation and parasitism, and the decline of pest populations. Nowadays, habitat management for pest population suppression is well established and multidisciplinary but requires close cooperation among practitioners and efforts focused on selecting plant species with minimal disruptive effect on crop growth while maximizing benefits from pest suppression by natural enemies.

The presentation focuses on the practical implementation examples of habitat islands for biological control of bagworms and slug moth on oil palm farms in Malaysia. The oil palm sector in Malaysia traditionally has planted four non-native Latin American plant species on roadsides without considering the limited flight range of some beneficial insects or the needed variety of insect resources. Nurtured by the experience with berry and maize farmers in Jalisco and Puebla (Pollinator Operation Mexico), a local alliance (CABI, Wild Asia, UPM) coordinated by SAN and funded by Ferrero has adopted the concepts of understory plant corridors and islands of Costa Rican oil palm farms and an insect network developed with the revision of 80 scientific publications. Ten native plant species for optimum insect resources were tested and monitored on oil palm smallholdings. The six most resilient plants in terms of herbivore attacks, adaptation to local climate and crop conditions, offering an optimum resource mix for predators and parasitoids were selected. Cost-effective planting methods (seed dispersal and integrated understory management) are additionally being tested on smallholdings and an Estate.

Session 16-O4 - Biodiversity-based pest management practices

Agrobiodiversity for sustainability crop pest management

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The monoculture of crops often leads to epidemic of plant diseases and outbreak of pest in agrosystem, while increasing the diversity of genetic, species and ecosystem level can suppress pest and disease, improve the productivity and sustainability. Study on both of structure and functional diversity to develop the technologies of environmental friendly management is increasingly concerned in the field of plant protection globally. Our works demonstrated that phytomicrobiome of rice, mainly derived by rice genetic diversity, contribute to plant resistance to diseases significantly. Moreover, the efficacy and mechanisms of using agrobiodiversity to control diseases were discuss in the presentation, and some esamples of pest management were introduced, aiming to provide more insights for the development of strategies for sustainable management of crop diseases.

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Session 16-O5 - Biodiversity-based pest management practices

Landscape composition and heterogeneity affects the abundance and diversity of coccinellids, and biological control in alfalfa fields in Central Chile

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Coccinellids (Coleoptera: Coccinellidae) are important natural enemies of pests in crops. Their abundance, diversity, and function may be affected by landscape composition and heterogeneity. In Chile, most coccinellids species are concentrated in the central part of the country, a very disturbed region. In this presentation we will summarize how native and exotic coccinellids in alfalfa differentially respond to the surrounding landscape. At a local scale, mark-recapture studies showed that field edges are important structures for coccinellid colonization to crops. At the landscape scale, the abundance of native and exotic species differs among cover types, depending on their disturbance. Natives are more abundant and diverse in alfalfa fields surrounded by more compositionally and configurationally heterogeneous landscapes, with more natural and semi-natural habitats, whereas exotics are less affected. Cage experiments have shown that biological control of aphids in alfalfa is positively associated with the abundance of native coccinellids and also with the area of some natural and semi-natural habitats such as woodlots, abandoned fields and sclerophyllous matorral. A more recent study evidenced that coccinellid density increases and aphid density decreases when alfalfa fields are surrounded by landscapes with a higher density of agricultural-natural habitats edges. These results highlight the importance of maintaining/restoring landscape compositional and configurational heterogeneity at different spatial scales in order to conserve aphidophagous coccinellids and pest control in alfalfa fields in Central Chile. FONDECYT 1070412, 1100159, 1180533, 1230073.

Session 17-O1 - Foodborne and plant pathogens biological control

Bridging research to practice: scaling aflatoxin biocontrol products through public private partnerships

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Aflatoxins, potent secondary metabolites produced by various *Aspergillus* species, significantly threaten food safety, public health, and domestic and international trade. Extensive research has successfully identified biocontrol agents based on atoxigenic *A. flavus* fungi effectiveness in mitigating aflatoxin in crops. However, significant efforts are required to bridge the gap between research and effective scaling of aflatoxin biocontrol products, a process in which regulatory approval is crucial. It is essential to foster collaboration between public and private sectors, establishing context-specific partnerships to efficiently manufacture and distribute biocontrol products. In addition, impediments in awareness, procurement of equipment and materials for production, distribution, and adoption must be overcomed. Public-private partnerships thus must facilitate production and deployment of biocontrol products, capitalizing on the strengths in both sectors. For the last two decades, IITA has aligned interests among researchers, government agencies, and private enterprises and within these partnerships. This has enabled the streamlining of regulatory processes and facilitated resource mobilization. In addition, advocacy for developing policies for aflatoxin control, creation of demand for biocontrol products through innovative institutional arrangements, campaigns for raising awareness, providing adequate farmer training, and establishing efficient supply chains are some of the measures promoted by IITA to scale biocontrol. The public-private partnerships are mitigating aflatoxin contamination and contribute to food security and public health in African countries. However, there is need for greater collaboration among research institutions, governmental bodies, and private entities to successfully scale aflatoxin biocontrol products in countries where the products are commercially available and in others where the process is ongoing.

Session 17-O2 - Foodborne and plant pathogens biological control

Application of probiotics as a biocontrol for *Salmonella* in chicken

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Probiotics are live microorganisms that confer a health benefit to the host. It is one of the leading biological control agents used in food animal production for growth promotion and disease prevention. However, their efficacy varies across studies and between animal models. In this study, we investigated the efficacy of a *Bacillus*-based probiotics as a biological control agent for *Salmonella* - a leading cause of human food borne illnesses linked to the consumption of poultry. In one study, we seeded fifteen-gram broiler chicken litter microcosms (n = 90) with probiotics and inoculated the microcosms with a cocktail of *Salmonella* Heidelberg strains and commensal *E. coli* strains. After 21 days of incubation in an environmental growth chamber (37°C and 60% relative humidity), microcosms seeded with probiotics had a faster *S.* Heidelberg die-off rate (k= -0.143 -1day, T90 = 7.00 days, R2 = 0.82) than unseeded control microcosms (k= -0.0991-1day, T90 = 10.09 days, R2 = 0.39) (*P* = 0.27). In a follow-up study, we challenged 1-day old broiler chicks (n = 260; 4 – 6 floor pens; 26 chicks/pen) with a cocktail of nalidixic resistant *Salmonella* Infantis strains and raised the chicks on either probiotic seeded litter or unseeded litter. After 7 days, chicken grown on probiotics seeded litter harbored a lower relative abundance of *S.* Infantis (n = 8; log10 -0.021 ± 0.28 copies/gapA) compared to chicken raised on unseeded litter (n = 8; log10 0.44 ± 0.31 copies/gapA) (*P* = 0.040). Together, these studies show that probiotics are promising biocontrol agents for food borne pathogens such as *Salmonella* that is commonly linked to poultry consumption.

Session 17-O3 - Foodborne and plant pathogens biological control

Application of competitive microbes, predatory bacteria and antimicrobials for biocontrol and inactivation of foodborne pathogens

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The food safety of agricultural commodities is important for consumer health. However, human pathogenic bacteria such as Salmonella, *Escherichia coli* and *Listeria monocytogenes* are persistent impediments to food and consumer safety. Biocontrol and biorational approaches for pathogen inactivation with beneficial microbes may be attractive pathogen reduction measures, due to cost effectiveness, low chemical residues, low potential for host-resistance, and specificity of pathogen control. We evaluated the efficacy of predatory bacteria (*Bdellovibrio bacteriovorus*), competitive exclusion microbes (CEM), generally regarded as safe (GRAS) antimicrobials and sanitizers for reduction of pathogenic bacteria in-vitro and on post-harvest produce. *B. bacteriovorus* and non-pathogenic CEM (*Pseudomonas* sp.) were applied against Salmonella or *E. coli* in-vitro and on produce either solely or in combinations with non-thermal measures. The reductions of *E. coli* and Salmonella by *B. bacteriovorus* in co-cultures ranged from 1.00-3.85 Log CFU/mL, while on lettuce, *E. coli* reductions were <1.84 log CFU/g but differed significantly ($p<0.05$) from the control. CEM microbes significantly ($p<0.05$) reduced Salmonella by 0.50-2.00 log CFU/g on tomatoes, relative to the control and had significantly ($p<0.05$) greater log reductions of Salmonella and *E. coli* O157:H7 in-vitro than on spinach. Pathogen inactivation by other antimicrobials were significant ($p<0.05$) but varied on produce and seed. These results indicate that biocontrol interventions offer a great potential for pathogen reductions and food safety.

Session 17-O4 - Foodborne and plant pathogens biological control

Organic tomato crop management by a bio-formulation based on PGPR: its effects on beneficial plant development and protection against vascular wilt disease

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Vascular wilt in tomato is a disease caused by the phytopathogenic fungus *Fusarium oxysporum*, and is the main threat to this crop. Usually, disease control is through agrochemical management, however, an environmental sustainable alternative is the implementation of biological control due to the negative impact of fungicides, pesticides and herbicides; since their residues leach in the soil, contaminate groundwater, and damage the ecosystem. In the present investigation, the growth inhibition of *F. oxysporum* by plant growth promoting rhizobacteria (PGPR) isolated from an organic strawberry orchard was demonstrated. We evaluated several traits to demonstrate that the bacteria used belong to the PGPR group, in addition, their molecular identification done by sequencing the 16S region. We obtained several PGPR genera such as *Achromobacter, Bacillus, Pseudomonas, Klebsiella, Chryseobacterium, Enterobacter* and *Pantoea.* The compatibility between selected bacteria was assayed to establish some consortia and thus analyze their antagonistic effect against *F. oxysporum* and their beneficial effect on tomato crops. We were able to establish two consortia DM1 (eight PGPR) and DM2 (seven PGPR), both of which inhibited the development of *F. oxysporum* by about 85%. Subsequently, the ability of PGPR to promote growth on tomato crops and their bioprotective effect against *F. oxysporum* was evaluated. We observed a positive effect, revealing a protection against the vascular wilt disease, since more than 90% of the plants did not show any signs of disease. Also the phenological effect on the plant (flowering, fruiting, vegetative development) was accelerated. Overall, our results showed that DM1 and DM2 consortia are excellent biological control agents, since they act as growth promoters and as biostimulants, as they simultaneously protect the plant against *F. oxysporum.* There is potential feasibility to implement utility of PGPR as a biotechnological tool in greenhouses.

Session 17-O5 - Foodborne and plant pathogens biological control

Regulatory approval of bioprotectants: lessons from registering multiple aflatoxin biocontrol products in Africa

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The biological control of insect pests, pathogens, and weeds is of increasing importance in the era of nature-positive agriculture. Significant R&D efforts are required to identify and scale effective and safe bioprotectants. A prerequisite for the commercial use of bioprotectants is their official registration by (bio)pesticide regulatory agencies through a time-consuming, resource-intensive, and cumbersome process. As a result, only a few bioprotectants among the many identified at the R&D phase are commercially used. In 2003, the International Institute of Tropical Agriculture (IITA) and its partners began to develop country- or region-specific biocontrol products in Africa, generically known as Aflasafe, for the mitigation of aflatoxin, which negatively influence food safety, food security, health, and trade. Each Aflasafe product contains four native isolates of *Aspergillus flavus* incapable of producing aflatoxins. To date, pesticide regulators have approved registration of 16 Aflasafe products for use on maize, groundnut, and sorghum in 12 African countries. IITA and the United States Department of Agriculture (USDA) began efforts to register aflatoxin bioprotectants in Africa in 2008 using experiences gained by USDA for registering the biocontrol product AF36 with the US Environmental Protection Agency. At that time, most African countries lacked guidelines for registration of bioprotectants. Therefore, regional workshops were conducted to guide the registration process and significant achievements have been made. It took 5 years from registration filing to approval for the first Aflasafe product (in Nigeria in 2014) while the last product (in Uganda in 2023) required about 6 months. One of the lessons learned while registering multiple products in Africa includes the need to involve regulators, local researchers, policymakers, and value chain participants at all stages of product development and testing so that they have a sense of ownership of the product.

Importance of host specificity in classical biological control against insect pests threatening livelihoods

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Nowadays, host specificity has become one of the major criteria for selecting natural enemies for introduction against invasive insect pests, to prevent non-target effects on native biodiversity. Many countries will only allow releases of parasitoids or predators if studies have chosen that the biocontrol agent will be highly specific to the target pest in the region of introduction. However, while exotic parasitoids and predators are mainly a concern for other insects, the pests that they are supposed to control often pose far more serious issues. In particular, some invasive agricultural pests in low-income countries threaten the livelihood of millions of farmers, causing malnutrition, diseases and even deaths, both through a decrease on food supply and through the massive increase of pesticide use, often without proper protection. The invasion of the fall armyworm (*Spodoptera frugiperda*) and the tomato pinworm (*Phthorimaea absoluta*) are good examples of such impacts on farmers and consumers. In such situations, the argument that a potential biological control agent should not be released because it may attack and affect populations of a non-target insect becomes less heard and understood. Balancing risks and benefits of the introduction of an agent should be part of all classical biological control programmes but, in practice, very few countries apply such approach, some being ready to release anything that can help solving the pest problem whereas others will remain very strict regarding potential non-target effects. It is hoped that this short introduction will generate a discussion regarding approaches on how to balance benefits and risks, especially in the case of pests threatening livelihoods.

Session 18-O2 - Classical biological control in sub-tropical Africa

Classical biological control for the sustainable management of papaya mealybug (*Paracoccus marginatus*) in East Africa

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The papaya mealybug (PMB), *Paracoccus marginatus*, a native to Mexico and Central America, invaded East Africa in 2016. This highly polyphagous pest causes yield loss of between 56.7–91.0%, and household economic losses of £2,224/ha annually in small holder papaya systems. Farmers manage the problem by spraying up to 16 times in a season, using synthetic pesticides, which could harm native insect biodiversity. Biological control is considered a more ecologically sound approach. Country wide surveys in Kenya revealed only 0.004% parasitism by native natural enemies, insufficient to maintain the PMB populations below economic-injury level. Consequently, *Acerophagus papayae* a koinobiont endoparasitoid of PMB was imported to Kenya in 2020. Pre-release studies showed that *A. papayae* successfully parasitized the three PMB instar stages. High parasitism rates of 72.5 ± 5.9 and 75.0 ± 3.8% were recorded in third instar and adult female PMB, respectively, and lower parasitism rates of 43.8 ± 4.6 % were recorded in second instars, under no-choice test scenarios. Significant differences in host choice were observed when *A. papayae* was offered several host stages, with third instars being preferred over second instars. Adult females were preferred over third instars. This study confirmed the potential of *A. papayae* as an effective biological control agent of PMB due to its ability to parasitize all the three PMB host stages, and development within short time. Consequently, field release of *A. papayae* were undertaken and establishment monitored at the coastal region of Kenya. *A. papayae* parasitoid was recovered within the first month of release from the open field. Parasitism levels varied across the sites, reaching 72.9% at some sites. This study highlights the potential of *A. papayae* as a good candidate for the classical biological control of PMB in East Africa beyond. Similar efforts have now been expanded to Uganda and South Sudan where PMB is a major threat.

Session 18-O3 - Classical biological control in sub-tropical Africa

Investigation, identification and study of the effectiveness of the natural enemies against the leafhopper *Jacobiasca lybica* (Hemiptera: Cicadellidae) under laboratory conditions

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Jacobiasca lybica (Bergevin & Zanon) (Hemiptera: Cicadellidae) is a polyphagous pest that damages grapevines in Europe and recently the citrus fruits in Morocco. Management of this insect is based mainly on chemical control, but there is an urgent need to develop an alternative management tool, such as biological control. In this study, we evaluated the predation rate of the first- to third-instar *Chrysoperla carnea* (Stephens, 1836) (Neuroptera: Chrysopidae) on *J. lybica* under laboratory conditions. The predation rate of each lacewing instar was determined 24 h after placing an individual lacewing larva in a Petri dish containing a freshly detached grape leaf with 15 adult and five immature leafhoppers. Furthermore, we investigated, identified, and evaluated the efficiency of entomopathogenic fungi against *J. lybica* under laboratory conditions. The fungi were isolated from leafhopper collected from a vineyard in the Berkane Province of Morocco, and then they were identified according to micro/macroscopic aspects and molecular identification before they were tested to evaluate their efficiency against this leafhopper. Our results indicated that the average predation rate by the third instar was 47.8%, which was significantly higher than that of the second instar (31.1%). The predation rate was not different between the first (21.7%) and second instars. The predation rates for leafhopper nymphs (46.7%) were significantly higher than for the adults (29.1%). Moreover, the study demonstrated four fungi that were chosen based on their different macroscopic aspects for further identification and pathogenicity tests. One strain of *Aspergillus* sp. had showed the most developed rate during the five days of the study. This promising result indicated that the selected fungus had shown some entomopathogenic effectiveness on leafhoppers. This can lead to a possible biological control to use in an integrated management against *J. lybica* in Morocco.

Session 18-O4 - Classical biological control in sub-tropical Africa

Controlling the fall armyworm using the push-pull strategy: trophic interactions and the potential for classical, and augmentative biocontrol for improved field efficacy

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The fall armyworm (FAW), *Spodoptera frugiperda*, poses a significant threat to food security in sub-Saharan Africa. The push-pull technology (PPT) offers a promising, sustainable approach to managing this devastating pest by manipulating trophic interactions within the agroecosystem. In its entirety, the PPT relies on the chemical profiles of the companion plants; *Desmodium* spp. that repel the fall armyworm and other cereal Lepidopteran pests whilst attracting their natural enemies; and *Brachiaria* grasses, which are planted around the plot, to lure the pests away from the crop for oviposition. These peripheral grasses act as a trap crop by arresting the development of emerging larvae. Apart from these direct above-ground interactions, recent field evidence shows that soil legacies of the PPT companion plants prime maize crops for enhanced constitutive and induced defence. Despite these important lines of defence, it is increasingly becoming apparent that the abundance and diversity of endemic parasitoids of FAW remain low in many invaded African regions since the pest is non-native and relatively new. Hence to maximize efficacy against FAW, an integrated biological control approach of both PPT and parasitoids such as *Telenomus remus* and *Trichogramma* can enhance pest control and *in situ* biodiversity conservation. The current paper will discuss these approaches with a call to action for an integrated area-wide strategy for effective control of FAW.

Management of *Phthorimaea absoluta* with introduced and native biocontrol agents

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Abstract

In the last decade, tomato, *Solanum lycopersicum* L. (Solanaceae), has been severely attacked by the tomato leaf miner, *Phthorimaea absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in Sub-Saharan Africa. Surveys with farmers showed that the use of insecticides increased since the invasion of that insect pest, thus risks associated with the residual effect of insecticides in edible food and the negative effects on ecosystem services may have also increased. The objective of this study was to investigate the management of *P. absoluta* with the introduced parasitoid, from Peru, *Dolichogenidea gelechiidivoris* Marsh (Hymenoptera: Braconidae), native parasitoids, and the entomopathogenic fungus, *Metarhizium anisopliae* ICIPE 20. Releases of *D. gelechiidivoris* was done after studies of its functional responses and the tri-trophic interactions between the parasitoid and native parasitoids. The maximum emergence of these wasps from parasitized hosts was obtained at a host pest density of 100 larvae. In a short-term competition between *D. gelechiidivoris* and the eulophid *Stenomesius sp. near japonicus*, the exotic wasps performed better than the native species. However, in a long-term competition exploration between *D. gelechiidivoris* and *Bracon nigricans* (Szépligeti), the native wasps negatively affected the increase of the *D. gelechiidivoris* population growth. The study of the potential use of the fungus *M. anisopliae* ICIPE 20 with *D. gelechiidivoris* revealed the fungus shortened the survival of parasitoid larvae as well as the longevity of the adult. However, the parasitism by fungus-infected females remained high (> 70%). A greenhouse trial was settled to confirm these results and fewer infested fruits with *P. absoluta* were harvested when both agents were applied. The establishment of the exotic wasps was confirmed with recovery, one year after its release. The findings of this work can be optimized to develop sustainable IPM methods to control *P. absoluta*.

Session 19-O1 - Biological control of plant diseases

How to manage the complexity of deploying microbial biocontrol agents against plant diseases?

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The control of plant diseases using microorganisms has been the subject of intensive research study over recent decades, leading to the identification of numerous beneficial microorganisms and the marketing of a growing number of microorganism-based biocontrol products. These micro-organisms can act according to different modes of action, which are increasingly well described. However, their protective efficacy under field conditions is often considered variable and sometimes unsatisfactory by the farmers and farm advisors.

Knowledge of the factors modulating the protective efficacy of microbe-based biocontrol products is essential to better guide their use in the field and their integration into integrated pest management strategies, and consequently their commercial success.

During this presentation, the various biotic and abiotic factors that can affect the protective efficacy of biocontrol microbes will be presented. The construction of a database gathering these factors, based on data collected in the scientific literature, will be explained. Finally, the perspective of developing decision-support tools to promote the use of biocontrol agents in the field based on this database will be discussed.

Session 19-O2 - Biological control of plant diseases

Challenges in using microbial antagonists on seeds to protect seedlings from diseases

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Seed applications with fungicides will be phased out in the European Union so that new alternative seed treatments will be needed in the future. A new generation of bacterial and fungal antagonists has to be selected and developed for seed applications to protect germinating seeds and seedlings from pre-emergence and post-emergence seedling diseases caused by *Pythium* spp., *Rhizoctonia solani*, *Fusarium* spp. and other seed or soilborne pathogens. Valid selection criteria are needed for such screening programs. Besides high efficacy, compatibility of the antagonists with the environmental conditions on seeds is a crucial requirement. Certain conditions during coating processes, drying steps, and storage, packaging and transportation of seeds through the distribution chain may be harmful for coated antagonists. Various steps in seed processing have been analysed and new valid screening assays are being developed. High throughput assays based on viability qPCR are introduced to assess the survival of coated antagonists under various conditions. These assays will be used to screen large numbers of candidate antagonists with the aim to exclude microorganisms that are vulnerable to the exposed conditions during seed coating and handling, storage and use of the coated seeds. Assays can also be used to modify seed processing steps allowing better survival of microorganisms during seed treatments.

Session 19-O3 - Biological control of plant diseases

Breeding for biocontrol: exploring genetic variation in biocontrol interactions

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In augmentative biocontrol, individuals from a single species typically display high variation in biocontrol efficacy. In order to investigate the basis for this phenomenon, we evaluated 63 genome-sequenced strains of the biocontrol fungus *Clonostachys rosea* for their ability to control fusarium foot rot disease on wheat, *in vitro* antagonism, plant growth promotion and growth rate on a range of different fungicides. There were significant ($P < 0.05$) differences between *C. rosea* strains in all investigated traits, and typically low correlations ($R^2 < 0.27$) between traits. This suggests a mechanistically different basis for these biocontrol-related traits, allowing for genotypic adaptation. A transcriptome analysis further identified induction of distinct gene sets in *C. rosea* following interaction with *Fusarium graminearum* or *Botrytis cinerea*, suggesting different mechanisms of antagonism towards different pathogens. In parallel, 200 genotyped wheat varieties were evaluated for their responsiveness towards *C. rosea*-mediated biocontrol of septoria tritici blotch disease. There was significant ($P < 0.05$) variation among wheat genotypes for biocontrol responsiveness, which allowed the identification of two genomic regions associated with the trait. In summary, we show a high degree of genotype-by-genotype effects on the outcome of biocontrol interactions, which opens opportunities for designing optimal biocontrol agent – crop combinations as well as biocontrol breeding programs. Genetic markers segregating with desirable traits in the biocontrol agent and the plant host can be used for marker-assisted selection in breeding programs.

Session 19-O4 - Biological control of plant diseases

Use of *Bacillus amyloliquefaciens* QST713 and *Clonostachys rosae* IK726 to control multidrug resistant strains of *Botrytis cinerea*

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Botrytis cinerea is classified as a high-risk pathogen for resistance development. Accumulation of target-site mutations and overexpression of efflux transporters can lead to Multiple (MLR) and Multidrug (MDR) resistance, respectively. Apart from contributing to fungicide resistance, little is known as to whether efflux pumps can also bind to secondary metabolites of potential biocontrol agents (BCAs), thus rendering MDR strains more resistant to BCAs. In this study, we tested the ability of *Bacillus amyloliquefaciens* QST713 (*Ba* QST713) and *Clonostachys rosea* IK726 (*Cr* IK726) to control the MDR strains both *in vitro* and *in planta*. *B. cinerea* strains with different types of multiple and multidrug resistance (MLR, MDR1, MDR1h) and sensitive strains were used. *Ba* QST713 was evaluated *in vitro* with the method of dual cultures in solid substrate and *Cr* IK726 with the development of the pathogen in the crude extract of the BCA. The *in planta* evaluation of the BCAs was carried out by applying them on bean plants, 24 h pre inoculation. Fludioxonil was used as a chemical reference treatment. The results concerning the *in vitro* experiments showed that both BCAs could effectively inhibit the growth of the strains. *Ba* QST713 caused an inhibition zone around the pathogen and reduced its growth by up to 60%, while *Cr* IK726 inhibited partially or even completely the growth of some strains. In *in planta* experiments, MDR strains were more susceptible to *Ba* QST713 than sensitive ones, highlighting a potential fitness cost of them. In conclusion, the BCAs can reduce disease incidence and severity caused by the resistant strains and in some cases, they provide similar or higher efficacy compared to fludioxonil. The use of BCAs shows high potential and is a promising way to manage MLR/MDR strains.

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Session 19-O5 - Biological control of plant diseases

Enterobacter cloacae and a bacteriophage of the pathogen *Erwinia tracheiphila* as biocontrol agents of cucurbit bacterial wilt of muskmelon

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Erwinia tracheiphila (*Et*) causes bacterial wilt, a fatal disease of several cucurbit crops that can cause up to 100% yield loss in the Midwest and northeastern quarter of the U.S. It is vectored by striped and spotted cucumber beetles. While current management relies heavily on insecticides, biocontrol could be a supplemental tool. We have screened bacterial and bacteriophage candidates for biocontrol of *Et* in muskmelon. In our initial growth chamber trials, we co-inoculated two-week-old plants with *Et* strain SCR3 and one of 19 bacterial strains reported to have biocontrol potential against other pathogens. Eight strains (*Pseudomonas fluorescens*, *P. putida*, *P. protegens, Enterobacter cloacae*, *E. tabaci, Burkholderia ambifilia*, *Serratia marcescens*, and *Paraburkholderia phytofirmans)* reduced wilt in the two weeks after inoculation in multiple trials. When we sprayed-inoculated these eight candidates three days before inoculating *Et*, only *E. cloacae* reduced bacterial wilt symptoms, suggesting that *E. cloacae* has a different mode(s) of action than the other candidates. Although interactions between *E. cloacae* and SCR3 *in vitro* showed that it could suppress SCR3 growth via iron competition, several of the candidates similarly showed superior iron competitiveness *in vitro*; we have not yet identified the *E. cloacae* mechanisms of action. To explore bacteriophage-based biocontrol, we isolated 21 *Et* phages from two cucumber beetle species from both Iowa and Kentucky. TEM images showed two distinct morphologies among the nine isolates examined, suggesting limited taxonomic diversity among the isolates. When the phage isolate FBB1 was spray inoculated onto leaves prior to *Et* inoculation by one or three days, FBB1 suppressed wilt. Combinatorial studies are being conducted with *E. cloacae,* FBB1, and non-pathogenic hosts for FBB1 as carrier bacteria to evaluate the possibility of additive or synergistic effects for biocontrol of bacterial wilt.

Session 20-O1 - Role of microbials in sustainable agriculture

Exploration of mycoviruses-mediated hypovirulent strain as plant vaccine to control fungal diseases of field crops

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That Chestnut blight was successfully controlled by using Cryphonectria hypovirus 1 has always been an example of biocontrol of plant diseases by mycoviruses. Here, we use Sclerotinia sclerotiorum hypovirulence associated DNA virus 1(SsHADV-1) to explore an alternative way to control diseases of field crops. SsHADV-1 was isolated from a sclerotium on diseased rapeseed and its virions could directly infect the hyphae of *S. sclerotiorum*, furthermore, SsHADV-1 could drive mycophagous insect as transmission vector. Most importantly, SsHADV-1 could convert its host from necrotrophic pathogen to an endophyte yet promote plant growth and resistance against crop diseases, and SsHADV-1 in fungus in plant also has the opportunity to infect field strains of *S. sclerotiorum*. We used SsHADV-1-infected strain as plant vaccine to inoculate rapeseed seeds, and found the vaccinated plants grew much better than non-inoculated plants in field and protect rapeseed against stem rot. Since *S. sclerotiorum* is a beneficial endophyte of gramineous plants, we vaccinated wheat and rice and found that the plant vaccine could also function well on wheat and rice. Using mycovirus mediated hypovirulent strains as plant vaccines may have potential advantages. First, mycoviruses have been found in numerous important crop pathogenic fungi, whether DNA mycoviruses or RNA mycoviruses may have the ability to convert pathogenic fungi into endophytes; second, vaccines can improve the overall disease resistance of plants during growth season; third, large-scale application of plant vaccine can also make mycoviruses highly accumulate in crop field and induce the decline of fungal pathogens.

Session 20-O2 - Role of microbials in sustainable agriculture

Selectivity of microbial biopesticides in crop protection

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Pathogens often have strong specificity for particular hosts. This specificity has the potential to influence the suitability and efficacy of microbial pathogens used in biocontrol because it determines how selective the biopesticide may be. Selectivity is governed by specific properties of the host-pathogen interaction and can operate at two levels: species specificity and genotypic specificity. Species-specificity influences the range of pest species that a microbial biopesticide can be used to control and the potential effects of application for non-target insects in agroecosystems. Genotypic specificity determines whether a microbial pathogen can kill all individuals in a pest population, or just a subset of the pests that carry particular susceptibility genes. We have studied these issues in microbial biopesticides targeting pests including *Helicoverpa armigera*, *Tuta absoluta* and *Trialeurodes vaporariorum*. In this presentation I will show data quantifying the risks that fungal pathogens targeting *H. armigera* create for beneficial insects such as bumblebee pollinators and predatory beetles. I will move on to describe how the co-application of biopesticides that target different insect pest species influences their control efficacy. Finally, I will present results of trials where we have attempted to enhance efficacy of fungal biopesticides by combining multiple pathogen strains to target a broader range of the host population. In each case, the specificity of host pathogen interactions can have unpredictable consequences for microbial biopesticide selectivity.

Session 20-O3 - Role of microbials in sustainable agriculture

Plant modifies fungal non-self recognition to facilitate mycovirus transmission

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Non-self recognition is a feature of life on earth and is considered an important mechanism for fungi to prevent the spread of molecular parasites in their populations. However, reports on whether and how plants may disrupt fungal non-self recognition are very rare. Here, we show that the horizontal transmission efficiency of mycoviruses between vegetatively incompatible *Sclerotinia sclerotiorum* strains is significantly higher *in planta* than *in vitro*. This phenomenon is accompanied by an increase in plant proline concentration upon *S. sclerotiorum* infection. Proline attenuates the non-self recognition reaction among fungi *via* scavenging reactive oxygen species, eventually facilitating mycovirus transmission. The application of hypovirulent *S. sclerotiorum* strains harboring hypovirulence-associated mycoviruses (HAV) together with proline substantially protects rapeseed plants against *S. sclerotiorum* in the field. Our finding reveals an unusual pathway for plants to counteract infection by phytopathogenic fungi, *via* weakening fungal non-self recognition and promoting spread of HAVs, and will form the base for developing a strategy to increase HAV horizontal transmission efficacy for the biocontrol of plant fungal diseases.

Session 20-O4 - Role of microbials in sustainable agriculture

The use of *Metarhizium rileyi* to control FAW in Zambia

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The PlantwisePlus programme is working towards empowering women and men smallholder farmers to manage evolving plant health threats, increase their incomes, improve food security and safety, and reduce biodiversity loss through the promotion of sustainable crop protection practices. One aspect of this goal is promoting the use of biological control in favour of chemical pesticides. In Zambia, a naturally occurring fungus, *Metarhizium rileyi*, has been found to infect fall armyworm (*Spodoptera frugiperda*) larvae. CABI and ZARI (Zambia Agricultural Research Institute) are working on developing this fungus, potentially, into a biological control agent for use in Zambia. Laboratory bioassays have shown that the fungus is effective against FAW larvae, especially the younger instars. Various aspects of development are under way: (i) Molecular work has enabled detection of the fungal isolate to ensure that the isolate applied to the field can be identified, (ii) Formulation development to ensure the fungus can be delivered to the FAW and (iii) Mass production of the isolate. All of these aspects are important in the conceptualization of biopesticide development.

Session 20-O5 - Role of microbials in sustainable agriculture

Effects on the sporogenesis and biocontrol functions of *Trichoderma* spp. by the mycoviruses

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Trichoderma spp. are known to impact host plant growth and defense activities. With the findings of the mycoviruses from *Trichoderma* spp., more and more effects on the sporogenesis and biocontrol functions of host induced by mycoviruses were known. In our research, Trichoderma harzianum partitivirus 2 (ThPV2) from *T. harzianum* strain (T673) showed higher mycelial density, conidiospore, and chlamydospore production than in the virus-infected strain T673-F, as well as moderately but statistically significantly improved biocontrol activity when compared with strain T673-F in the experiments with cucumber seeds inoculated with *Fusarium oxysporum* f. sp. *cucumerinum*. Trichoderma harzianum mycovirus 1 (ThMV1) from *T. harzianum* strain (T525) not only affected the phenotype of the host strain but also reduces its biocontrol function on *F. oxysporum* f. sp. *cucumerinum*. Using the yeast two hybrid nuclear system to screen, 57 proteins involving the interaction between T525 and ThMV1 have been obtained, among which 40 proteins interacted with ThMV1-RdRP, 29 proteins interacted with ThMV1-CP and 12 proteins interacted with both ThMV1-RdRP and ThMV1-CP. For the hexokinase1 (HXK) also was the interacted protein with ThMV1-CP, the hexokinase gene (*hxk*) knockout mutant ($T525^{-hxk}$) and reverse mutant ($T525^{Rhxk}$) of T525 were obtained. connecting the results of transcriptomic analysis, Real-time RT-PCR and the phenotype of cucumber, the interaction of ThMV1-CP/HXK in T525 was proved to negatively regulate the disease resistance pathway of T525 and positively regulate the growth promotion effect of T525 in the cucumber.

Session 20-O6 - Role of microbials in sustainable agriculture

Collection of endophytic nematophagous strains and their potential in the control of phytoparasitic nematodes in tomato

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Solanum lycopersicum L. is of great relevance globally, due to its nutritional contribution and for being an excellent source of antioxidants; however, it is susceptible to various diseases caused by phytopathogenic agents such as plant-parasitic nematodes (PPN). There are different methods of controlling PPN, with chemicals being the most used, but they have negative externalities towards the environment and people's health. The use of nematophagous fungi (NFs) and in particular endophytic nematophages emerge as a sustainable alternative with high potential for controlling particularly root-knotting NFs. The objective of this research was to form a collection of native NFs, evaluate their endophytic capacity in tomatoes and their potential as biocontrollers of PPN. Strains of NFs were isolated by using nematode-baits, which were identified at the species level with molecular techniques. Tomato plants were inoculated with suspensions of 1x106 conidia mL-1 to the root. The fungi were subsequently reisolated from leaves, stems, and roots by culturing pieces of plant tissue on noble agar medium. Finally, its pathogenicity was confirmed in vitro using the *Sterneinema* nematode as a study model. As a result, a collection of 16 strains of NFs belonging to the genera Beauveria, *Metarhizium*, *Paecilomyces*, and *Metapochonia* was formed, of which 14 presented the capacity for endophytic colonization in tomato, with different colonization patterns and 14 strains of parasitized the Sterneinema nematode. NFs can colonize endophytically in tomatoes and potentially control PPN, so they could constitute a tool for the sustainable management of root-knot nematodes that are difficult to control.

Session 20-O7 - Role of microbials in sustainable agriculture

Biological control of tawny crazy ants with the microsporidian pathogen *Myrmecomorba nylanderiae*: the need for a Central American program

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Tawny crazy ants (*Nylanderia fulva*), an environmentally damaging, supercolonial invasive ant species, are rapidly spreading in Costa Rica and Panama. This ant, originally from South America, previously invaded much of the Gulf Coast region of the United States. Working in this North American context, we have developed a highly effective biological control program utilizing the microsporidian pathogen, *Myrmecomorba nylanderiae*. Local-supercolonies of tawny crazy ants create dense, interconnected, networks of nests that can span tens of square kilometers. Within these areas, they eliminate native ants, strongly suppress general arthropod diversity and abundance, and can prevent successful reproduction by ground and tree nesting vertebrates. The introduction of *M. nylanderiae* into uninfected local-supercolonies of tawny crazy ants, either naturally or through inoculation, consistently leads to the widespread collapse of the tawny crazy ant infestation within 2 to 5 years. This talk will describe the biology of this host-pathogen interaction, the population-level consequences of epizootic outbreaks of this disease, and current state of the use of this pathogen as a biological control agent. In North America, where *M. nylanderiae* occurs naturally, these findings create the opportunity to accelerate the decline of infestations and protect environments of high conservation value. The status of *M. nylanderiae* in Central America deserves investigation. These results also highlight the importance of research into the pathogens of invasive organisms in which clonal or colonial biology make intragroup transmission the primary driver of population-level disease prevalence. Organisms such as these may be susceptible to boom – bust dynamics and pathogen driven local extinction.

Session 20-O8 - Role of microbials in sustainable agriculture

Distribution of *Trichoderma rifaii* CT5 Colonization in *Coffea arabica*: insights into plant-endophyte dynamics

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Many *Trichoderma* species are well known for their ability to inhibit the growth of soilborne pathogens and promote plant growth. However, few studies have been conducted to assess its distribution in the plant over time. Herein, we evaluated the colonization patterns of *Trichoderma rifaii* CT5, a promising biocontrol agent recovered from wild Rubiaceae, across nine different tissues of *Coffea arabica* var. Caturra. These tissues encompassed: the initial 1 cm and 2 cm segments of lateral roots, the primary root, the root crown, petioles of the cotyledons, the cotyledons themselves, the internode, the first true leaves, and their petioles. The study determined the incidence of *T. rifaii* CT5 mycelium at 2, 7, 35, 50, and 120 days post-inoculation (dpi) in drench through destructive sampling of five plants, with subsequent culturing of sections in PDA medium Results indicated that *T. rifaii* CT5 colonized the root system within 2 dpi, encompassing its presence in lateral roots, the primary root, and the root crown. By 25 dpi, the endophyte had extended its colonization to include the petioles of cotyledons and the internode, with further progression observed by 50 dpi, reaching the petioles of the first true leaves. By 120 dpi, it had established colonization in the first true leaves of 80% of the samples. This research reveals the enduring stability of the endophyte within the *C. arabica* plantlet over the observed timeframe, demonstrating its widespread colonization throughout the plant tissues. The characterization of the establishment of *T. rifaii* CT5 across various parts of the plant, particularly on aerial components, can provide novel insights into its potential interaction with leaf pathogens for controlling foliar diseases.

Session 20-O9 - Role of microbials in sustainable agriculture

Use of entomopathogenic nematodes for management of cuculionids larvae cryptically located

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The entomopathogen nematode (EPN) *Steinernema austral* was first isolated in Chile and identified as a good alternative for controlling *Aegorhinus superciliosus* (Coleoptera: Curculionidae) larvae. This weevil is native to the south of Chile and some regions in Argentina, causing berries orchards to decline and die. The major problem is caused by the larva, which spends between nine to eleven months below ground and feeds inside the root-making galleries. This study seeks to increase *S*. *australe*'s efficacy through an artificial odor stimulus selection process. We selected *S*. *austral* infective juveniles (IJs) that follow the stimulus and reach the larva at 30 cm deep faster. Larvae infected with selected IJs and IJs from the original stock were compared under laboratory, greenhouse, and field conditions. Insect mortality and EPN penetration were analyzed using ANOVA with the number of dead larvae and IJs that penetrated the larvae as response variables. Results showed a 20% increase in the efficacy of selected IJs compared with IJs from the original stock. The most remarkable effect of the selection process on *S*. *austral* was the increase in the proportion of IJs that reached the larva faster, vertically down in the soil, during the first four days' post-application. Moreover, larvae treated with selected IJs depleted, showing a mix of nematodes' stages emerging from the cadaver. A potential trade-off on nematodes' recycling in the soil is proposed. This is the first report focusing on the effect of artificial selection to increase the efficacy of *S*. *austral* in the field.

Session 21-O1 - Modeling biological control interactions

Trait-based approaches to predicting biological control success: challenges and prospects

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Identifying traits that are associated with success of introduced natural enemies in establishing and controlling pest insects has occupied researchers and biological control practitioners for decades. Unfortunately, consistent general relationships have been difficult to detect, preventing a priori ranking of candidate biological control agents based on their traits. We summarise previous efforts and propose a series of potential explanations for the lack of clear patterns. We argue that the quality of current datasets is insufficient to detect complex trait–efficacy relationships and suggest several measures by which current limitations may be overcome. We conclude that efforts to address this elusive issue have not yet been exhausted and that further explorations are likely to be worthwhile.

Session 21-O2 - Modeling biological control interactions

Dynamic economic thresholds for insecticide applications against agricultural pests: importance of pest and natural enemy migration

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In Integrated Pest Management programs, insecticides are applied to agricultural crops when pest densities exceed a predetermined economic threshold. Under conditions of high natural enemy density, however, the economic threshold can be increased, allowing for fewer insecticide applications. These adjustments, called 'dynamic thresholds', allow farmers to exploit existing biological control interactions without economic loss. Further, the ability of natural enemies to disperse from, and subsequently immigrate into, insecticide-sprayed areas can affect their biological control potential. We develop a theoretical approach to incorporate both pest and natural enemy movement across field borders into dynamic thresholds and explore how these affect insecticide applications and farmer incomes. Our model follows a pest and its specialist natural enemy over one growing season. An insecticide that targets the pest also induces mortality of the natural enemy, both via direct toxicity and reduced resource pest densities. Pest and natural enemy populations recover after spraying through within-field reproduction and by immigration from neighboring unsprayed areas. The number of insecticide applications and per-season farmer revenues are calculated for economic thresholds that are either fixed (ignoring natural enemy densities) or dynamic (incorporating them). The model predicts that using dynamic thresholds always leads to reduced insecticide application. The benefit of dynamic thresholds in reducing insecticide use is highest when natural enemies rapidly recolonize sprayed areas, and when insecticide efficacy is low. We discuss real-life situations in which monitoring of natural enemies would substantially reduce insecticide use and other scenarios where the presence of beneficial organisms may lead to threshold modifications.

Session 21-O3 - Modeling biological control interactions

A new framework for benefit-risk analysis for biological control introductions

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There is broad recognition within the biological control community that a framework incorporating both benefits and risks is needed to understand the net environmental effects of biological control releases. We introduce such a framework, using native biodiversity as the common currency for both benefits and risks. The model is based on interactions among four types of organisms: (i) the biological control agent, (ii) the invasive species (pest or weed) targeted by the agent, (iii) one or more native species that stand to benefit from the control of the target species, and (iv) one or more native species that are at risk of being harmed by the released biological control agent. Conservation values of the potentially benefited and harmed species are incorporated as well, and they are weighted according to three axes: vulnerability to extinction, the ecosystem services they provide, and their cultural significance. Further, we incorporate the potential for negative indirect effects on native species, which we consider to result mainly from the ecological process of agent enrichment that may occur if the agent exploits but does not control the target pest or weed. These elements are combined in an algorithm to produce a benefit-risk index, and uncertainty is incorporated by constructing 'pessimistic' and 'optimistic' scenarios resulting from a biological control release. We illustrate the use of this framework by retrospectively analyzing the release of the vedalia beetle, *Novius* (= *Rodolia*) *cardinalis*, to control the cottony cushion scale, *Icerya purchasi*, in the Galapagos Islands.

Session 21-O4 - Modeling biological control interactions

The joint action of *Trissolcus japonicus* and *Trissolcus mitsukurii* in biological control of *Halyomorpha halys* in Italy

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Classical Biological Control of invasive stink bugs with egg parasitoids is considered the most effective strategy for controlling invasive stink bug populations. Intentional introductions of the egg parasitoid *Trissolcus japonicus* (Ashmead) (Hymenoptera: Scelionidae) have been carried out in Italy since 2020 for the control of the invasive *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae). The establishment and the increase of *T. japonicus* over the years is driving a decrease in *Trissolcus mitsukurii* (Ashmead) (Hymenoptera: Scelonidae), another adventive egg parasitoid of *H. halys* recorded in Italy since 2016. The decline of T. *mitsukurii* seems to be driven by the competition with *T. japonicus* and the action exerted by the hyperparasitoid *Acroclisoides sinicus* (Huang and Liao) (Hymenoptera: Pteromalidae). Since each life stage of an insect has specific environmental requirements that describe the transition from one stage to another, we used a stage-structured matrix model to estimate the population growth of *H. halys* in northern Italy, implementing the parasitism observed by exotic *Trissolcus.* We observed that *T. mitsukurii* was the main biotic factor responsible for the decline in *H. halys* net reproductive rate (Ro) in the past years. Still, an essential role is expected to be played by *T. japonicus* in the future. Overall, the joint action of the two exotic *Trissolcus* is currently reducing the *H. halys* population.

Session 21-O5 - Modeling biological control interactions

Modelling the interactions of *Pseudococcus* biological control agents on vineyards and its implications in virus spread

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Mealybugs are serious agricultural pests worldwide. *Pseudococcus viburni* is the main species present on Chilean vineyards and its biological control in commercial fields relies on predators and parasitoids, in particular the generalist coccidophagous ladybird *Cryptolaemus montrouzieri* and the specific parasitoid *Acerophagus flavidulus*. However, these two natural enemies can establish an intraguild predation interaction, reducing the efficiency of biological control. *C. montrouzieri* may negatively impact the population dynamics of *A. flavidulus* if it feeds indifferently on healthy and parasitized mealybugs. With the aim of improving the Pseudococcidae biological control, in this work, we studied the feeding behavior of *C. montrouzieri* in the absence or presence of *A. flavidulus* larvae of different age within mealybugs, in laboratory conditions. Subsequently, with the data obtained, we mathematically modeled the dynamics of *P. viburni* to study the impact on *P. viburni* control of different field implementation schedules for the release of ladybird and parasitoid populations. The ladybird fed on parasitized *P. viburni* but reduced its consumption when they were infested by parasitoids aged of 4 days or more. Modelling results suggest that these feeding preferences of predators may have a positive impact on pest control, that releasing predators and parasitoids together is in general more effective than releasing them independently, and that releasing highly effective predators alone could be the best choice. Modelling results also provide information on different release schedules. Afterwards, we present a mathematical model to represent the dynamics of Grape Leaf Roll Virus in vineyards and vector population impacted by biological control.

Session 22-O1 - Socio-economics of biological control

Synthesis of the global economic impact of classical and conservation arthropod biological control

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Biological control of insect pests is an integral tactic of modern integrated pest management. The number of studies quantifying the economic benefits of biological control remains small, yet estimates suggest biological control has immense value. Here we present economic concepts and methods for placing an economic value on biological control services with focus on classical and conservation approaches. We then summarize and synthesize the extant studies that have attempted to quantify the economic outcomes of the biological control of arthropod pest with natural enemies. Value varies depending on the managed system under consideration and on the assumptions embedded in the estimates.

Session 22-O2 - Socio-economics of biological control

Economic impact of a classical biological control program: application to *Diachasmimorpha longicaudata* against *Batrocera dorsalis* fruit fly in Kenya

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Classical biological control (CBC) has been exploited as a safer alternative for suppressing the oriental fruit fly, *Bactrocera dorsalis,* by importing, rearing, and releasing the larval parasitoid, *Diachasmimorpha longicaudata.* Although *D. longicaudata* has been released in Kenya through the Africa Fruit Fly Programme, the extent of its dispersal and subsequent economic benefits have not yet been established. This paper models the spatiotemporal dispersal of the parasitoid using the fuzzy cellular automata approaches and estimates the net benefit from each dollar invested in the CBC approach. We calculated the return on investment based on funding into the programme between 2006–2015 and the result of the dispersal range of the parasitoid predicted using an artificial intelligence algorithm. The investment yielded a significant net present value of US$42.8 million over the 16 years. Besides, the cost-benefit ratio showed that for every US$1 invested, the return benefit was US$93, confirming the profitability of the CBC program. The economic gains are significant considering that there is no environmental contamination and possible adverse effects from the CBC intervention. The study findings support investment in biological control strategies for the eco-friendly and area-wide management of *B. dorsalis*.

Session 22-O3 - Socio-economics of biological control

Adoption and impact of bioprotection products in Bangladesh

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Despite the recognition that bioprotection products are safer and environmentally-friendly alternatives to the widely used synthetic pesticides for pest control, adoption remains very low in many developing countries. Among the major obstacles to the adoption of bioprotection products (besides lack of awareness and unavailability) is farmers' perceptions and misconceptions about their efficacy and cost-effectiveness, particularly when compared to synthetic pesticides. However, studies examining the effectiveness of bioprotection products are usually conducted under laboratory or field experimental conditions, which are not an accurate reflection of how well they will perform when adopted by smallholder farmers, given that farming conditions can impact the effectiveness of the products. The current study aims to contribute to addressing this gap in the literature by assessing the effectiveness of biopesticide use in a non-experimental set-up in Bangladesh. A farm household survey among a representative sample of 800 brinjal and 700 mango producers in Bangladesh has recently been completed. Data will be analysed using instrumental variable regression methods. The presentation will examine whether the adoption of bioprotection products increases crop yields and reduces incidence of acute pesticide poisoning, and the extent of yield penalty from adopting bioprotection products rather than synthetic pesticides.

Session 22-O4 - Socio-economics of biological control

Perceptions and willingness to use biological controls for fall armyworm in Zambia, a gendered perspective

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CABI is currently testing two alternative biocontrol methods as lower risk options for management of fall armyworm (*Spodoptera frugiperda*) (FAW) on maize crops in Zambia. The biocontrol methods being piloted include a local Zambian strain of the entomopathogen *Metarhizium rileyi* and a commercial baculovirus, Fawligen. The objective of this study was to understand gendered access to and control over resources, time-use patterns and intra household gender dynamics related to pest management for men and women maize farmers. Gender assessments were carried out in four districts involving purposive sampling to select primary men and women in dual headed households, and single women headed households for individual interview (total 522 participants; 338 women and 184 men). In each district, focus group discussions took place with men, women, and youth (total 16) and key informant interviews were conducted at district and camp level.

Results highlight a high prevalence of women-headed households and women's major role in maize production and pest management. Women's access to resources is more constrained than men's resulting in women, especially single women household heads, relying on cultural methods to manage FAW including hand-picking and application of ash, neem, and sand. Men rely more on chemical pesticide application. Camp extension officers and lead farmers are central to information provision and training. There are currently low levels of awareness and use of biological control across the districts but high levels of interest and willingness to use biocontrols as another tool in the fight against FAW. The proposed biocontrols would be beneficial especially to women farmers at the forefront of managing FAW. The development of a gender action plan, also considering youth perspectives, is underway to outline how to enhance women's engagement in the use of lower-risk alternatives to control FAW alongside strengthening gender equity within these farming communities.

Session 22-O5 - Socio-economics of biological control

Local biopesticide production hubs – insights on business models and evidence of women's empowerment from Bangladesh and India

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Strides have been made in Bangladesh to promote the utilisation of biological control agents (BCAs); however, farmer utilisation remains sub-optimal. The establishment of local production hubs, although touted as a panacea to this problem, has no proven business case. We employ qualitative and quantitative data from maize growing areas in Bangladesh to make the case for a non-linear business model. With insights from key informants representing four key stakeholders national research institute, regional research stations, farmer producer organisations, and agrodealers, we elaborate on the factors hindering farmer uptake of BCAs in Bangladesh using the case of FAW management. We propose a multistakeholder innovation systems-based business model that translates into the establishment of local BCA production hubs owner-managed by farm entrepreneurs, with regional scientists providing them with nucleus culture, while extension services provide technical support for quality assurance and increasing awareness of BCA amongst farmers.

As part of making the case for the establishment of local biopesticide production hubs, we showcase the establishment of local biopesticide production hubs, some of which are established and operated solely by women, provide environmentally friendly plant pest solutions, and are linked to a network of plant clinics. Study findings show that women in India who are engaged in cottage industries have increased their empowerment via the operation of local production hubs for biopesticides. We have seen evidence of empowerment in several aspects: (i) women have control over their participation in and income from cottage industries, (ii) women participate in household decision-making processes, and (iii) participation in community groups amongst interviewed women is very high.

These two cases from Bangladesh and India jointly showcase the feasibility of establishing local biopesticide production hubs and their potential to empower local rural communities.

Session 23-O1 - Adoption of IPM for successful biological control

Old and new thrips species causing trouble: adjusting greenhouse biocontrol programs to manage multiple thrips species

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Historically, thrips problems in greenhouse crops were caused by Western flower thrips (WFT), *Frankliniella occidentalis*. Due to its rapid development of pesticide resistance, this species has contributed significantly to the development and adoption of biological control in Canada, especially in floriculture greenhouses. Recently, growers have observed an increase in thrips outbreaks, several of which were associated with an "old" thrips pest, onion thrips (OT), *Thrips tabaci*. In addition, a new invasive pest, pepper thrips (PT), *Thrips parvispinus*, was recently found in greenhouse tropical plants. Neither OT nor PT are adequately controlled by standard biocontrol programs that were previously effective for WFT. Yet, intensive use of pesticides to control these new pests will lead to a resurgence of WFT by killing their biocontrol agents, and will increase the risk of pesticide resistance in OT and PT as well.

This presentation will give an overview of the research done in Ontario, Canada. First, to determine the extent of the problem, an inventory was made of thrips populations in commercial floriculture, vegetable and other greenhouses in Ontario. Using the data gathered in these surveys, a simplified identification key was developed for use by growers and IPM consultants, supported by workshops on how to sample and identify thrips. Laboratory trials examined the relative efficacy of commercial biocontrol products to manage OT compared to WFT, including phytoseiid mites, *Orius insidiosus*, *Beauveria bassiana* and entomopathogenic nematodes. These biocontrol products are now being tested in greenhouse trials to validate the results. Finally, a new project will start soon on control of PT, integrating the lessons learned from OT and WFT.

Session 23-O2 - Adoption of IPM for successful biological control

The intersection of weed management, biopesticides, and biological control to manage aphids on winter crops

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Aphids are a primary pest on winter grown crops in high tunnels across the midwestern and northeastern United States. However, biocontrol recommendations for aphid management are largely tailored to summer crops where long daylengths and warm temperatures facilitate high product efficacy. In addition, activity by resident natural enemies and how non-crop vegetation affects aphid and natural enemy establishment during winter is largely unknown. This talk will describe natural enemy complexes present on 35 high tunnel farms across the U.S. and will introduce a pest management program that integrates biopesticide sprays and biocontrol predators that is effective in winter conditions. This study was conducted on high tunnel spinach and evaluated four commercially available biocontrol agents (*Aphidius ervi*, *Chrysoperla carnea*, *Orius insidiosus*, and *Adalia bipunctata*) crossed with three biopesticides (Silmatrix®, PyGanic® and Neemix®). Predator survival, prey consumption, and cost-efficacy were compared. Parasitoids and spiders were the most observed natural enemies on farms, and *Lamium amplexicaule* and *Stellaria media* were common weeds harboring aphids that infest spinach. Our lab and field studies demonstrated that all commercial biocontrol agents were compatible with biopesticides and were able to prevent aphid outbreaks. Among the treatments, *C. carnea* alone or when paired with PyGanic, was the most cost-effective option to improve marketable spinach yield. Overall, we predict that thoughtful weed management paired with biocontrol, with or without biopesticide intervention, is likely to be a successful IPM program for aphids in winter production.

Session 23-O3 - Adoption of IPM for successful biological control

IPM and biological control in coffee

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Several natural enemies are found in coffee crops, including green lacewings. *Chrysoperla* spp. have long been considered important natural predators in many agricultural crop systems. In some countries around the world, they are among the most commonly used and commercially available natural enemies. Currently, two species of *Chrysoperla* (*C. carnea* and *C. rufilabris*) are rear and marketed in North America and Europe. Two other species, *C. externa* and *C. nipponensis*, are marketed in Latin America and Asia. In Brazil, the species *C. externa* has been registered with the Ministry of Agriculture for commercialization. There are five Brazilian companies that have obtained registration, with the first registration obtained in November 2021. Currently, the green lacewing predators are released in Brazil in large crops, such as coffee plantations, covering approximately 150,000 hectares per year. Recent research conducted at the University of Franca by a team led by Professor Alessandra Marieli Vacari indicated positive results in the control of the coffee leaf miner, *Leucoptera coffeella* (Lepidoptera: Lyonetiidae), using predators from the family Chrysopidae (Neuroptera), both in laboratory and field conditions. Thus, the results obtained confirm the effectiveness of using the predator *C. externa* for the control of the coffee leaf miner. Moreover, these research studies open up the concrete possibility of increasing the utilization of these predators in Brazil, both for a larger treated area in coffee plantations and for other pests and crops as well. However, Professor Vacari's team is continuing their ongoing studies to ensure the success of this new biological control program in Brazil.

Session 23-O4 - Adoption of IPM for successful biological control

Multiple effects of baculoviruses and their use in IPM strategies

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Widespread use of synthetic chemical pesticides causes growing concern regarding the risks to human health and negative impacts on the environment. Baculoviruses bring many benefits and allow reduced use of synthetic chemical insecticides, when included in integrated pest management (IPM). They are specific to their target pest and thus do not have any negative effects on plants, mammals, and non-target insects such as beneficials and pollinators. In addition, their unique mode of action makes them suitable for resistance management. We provide examples demonstrating additional effects Baculoviruses can have on insect population growth besides to direct mortality of the treated larvae. We conducted lab trials with the products Tutavir (active ingredient Phthorimaea operculella granulovirus) and Helicovex (active ingredient Helicoverpa armigera nucleopolyhedrovirus). The results give an idea how these products can affect population development even in generations following the application. This demonstrates the potential of including baculoviruses into spray programs for better population management resulting in an environmentally friendly pest control without posing a risk for human health. In conclusion, baculoviruses fit into a sustainable approach for IPM strategies.

Session 23-O5 - Adoption of IPM for successful biological control

Ecological and economic feasibility of mass production of biological agents to control tomato moth, *Tuta absoluta* (Meyrick) (Lepidoptera, Gelechiidae) in protected culture

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Tuta absoluta is a major pest of tomato crops in the Mediterranean basin. The current maintenance of the pest populations below the economic threshold is not achieved by natural and classical control, thus requiring the continuous application of biological control agents, under an augmentative or inoculative approach. The ECO^2-TUTA project developed for 4 years aimed i) to seek and to test the efficacity of native natural enemies recorded for Portugal, against *T. absoluta* and ii) to develop an economic and financial model to evaluate the commercial viability of a continuous mass production of the natural enemies against the tomato moth in protected culture. *Macrolophus pygmaeus* and *Trichogramma achaeae*, were found to be the best candidates for futures biological control programs. However, feral populations of M. pygmaeus collected in Portugal mainland and the Azores archipelago fed under single prey diet, either of *Ephestia kuehniella* eggs, revealed the existence of phenotypic differences in several life history traits. Our results on feeding preference and intraguild interactions between *M. pygmaeus* and *T. achaeae* showed that the predator prefers unparasitized eggs of *T. absoluta* but inflicts intraguild predation on *T. achaeae.* In conspecific experiments, mutual interference between *M. pygmaeus* predators intensifies as the number of individuals increases, but for *T. achaeae*, it occurs in an unpredictable manner. Field releases of *T. achaeae* and *M. pygmaeus* could significantly increase the level of control of *T. absoluta* compared to what could be achieved when only *M. pygmaeus* is present in greenhouse tomatoes. The results of the farm-level analysis show that the adoption of a more sustainable biological control approach is profitable for farmers and the benefit-cost analysis provides evidence that the investment on a new factory dedicated to the mass rearing of *M. pygmaeus* to control tomato moth populations generates a positive Net Present Value (NPV) of 7.2 million euros, corresponding to an Internal Rate of Return (IRR) of 28.4% per year. Our results are an important contribution the more recent European Commission proposals for a new regulation on sustainable use of plant protection products, which includes the reduction of 50% the use and risk of chemical pesticides by 2030.

Session 23-O6 - Adoption of IPM for successful biological control

Coexistence and competition of two armyworms and implications for IMP

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Both the native African armyworm (*Spodoptera exempta*), cotton leafworm (*Spodoptera littoralis*) and the invasive fall armyworm (*Spodoptera frugiperda*) threaten food security in Africa. The invasion of *S. frugiperda* in Africa has created a scenario where these *Spodoptera* species might co-occur and interact with each other. This could have implications for pest management, including biological control and the effectiveness of management practices.

Given that *S. frugiperda* is much more aggressive than *S. exempta*, this study predicted that *S. frugiperda* would predate *S. littoralis* and *S. exempta*. Where the two species co-occur, *S. frugiperda* would dominate the intra-guild interaction. A number of experiments were carried out to understand the interactions between *Spodoptera* species. Laboratory contest studies with artificial diets were used to understand cannibalism/predation. Field observations of *Spodoptera* species on maize included the systematic sampling of smallholder maize farms in Arusha, Tanzania. This study found that, unlike the other two species, the cannibalism rate in *S. frugiperda* is higher, and when in competition with *S. littoralis* or *S. exempta*, *S. frugiperda* often wins the contest. *S. frugiperda* and *S. exempta* larvae can co-occur in the same field and on the same plant, and leaf. The interactions between *S. frugiperda* and *S. exempta* should also be considered when choosing a management strategy. There is a need to encourage different natural enemies, as the effectiveness of *S. frugiperda* and *S. exempta* natural enemies can differ. Encouraging natural enemies shared by both *S. frugiperda* and *S. exempta* could be effective.

Abstracts
Poster Presentations

Session 1-P1 - Aquatic weed biological control

First report of native waterlily leaf beetle (*Galerucella nymphaeae*, Coleoptera: Chrysomelidae) feeding on invasive parrot's feather watermilfoil (*Myriophyllum aquaticum*, Haloragaceae) in Canada

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Parrot's feather watermilfoil (*Myriophyllum aquaticum*, Haloragaceae) is an invasive, semi-emergent aquatic plant native to South America, which was likely introduced around the world via the aquarium or aquatic horticulture trade. In the invasive range, it can rapidly outcompete native aquatic vegetation, forming dense, monotypic stands that block drainage canals and clog pump stations, degrade habitat for both native plants and animals and negatively impact recreational opportunities. At present in Canada there are no approved chemical controls and mechanical controls like dredging provide only temporary relief, before rapid recolonization. As a result, the potential for biocontrol of parrot's feather in Canada is being explored, based in large part on a successful biocontrol programme in South Africa using an undescribed *Lysathia* species (Coleoptera: Chrysomelidae). We have been conducting invader impact and pre-release studies on all identified invasive populations of parrot's feather in south-western British Columbia, Canada. During the course of these studies we detected damage to emergent stems consistent with that caused by *Lysathia* sp. in South Africa at one of our study sites. Using genetic and morphological identification techniques, we have conclusively and for the first time in Canada, identified the native, holarctic waterlily leaf beetle (*Galerucella nymphaeae* L., Coleoptera: Chrysomelidae) as the cause of this damage. *Galerucella nymphaeae* is polyphagous, and has been documented feeding on other non-native species in North America; but has not been previously documented on parrot's feather in Canada, nor has it been credited with contributing to control of other invasive species. However, *G. nymphaeae* has also been shown to readily evolve host-races with high fidelity for the species they were reared on. Indeed at our study site, waterlilies and other nearby vegetation appeared relatively undamaged by *G. nymphaeae*. The potential for artificial selection of native species for biocontrol provides an intriguing possibility in this system.

Session 2-P1 - Biological control and the agroecology toolkit

Assessment of a tachinid fly and an egg parasitoid as biocontrol agents of *Edessa meditabunda* (Hemiptera: Pentatomidae)

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Phytophagous stink bugs are major pests of several crops. Among them, *Edessa meditabunda* (Hemiptera: Pentatomidae) has gained greater importance in the Neotropics in the last two decades. We aimed to evaluate the performance of two parasitoids of different guilds, as potential candidates for the biocontrol of *E. meditabunda*: the tachinid fly *Neobrachelia edessae* which exploits adults as hosts and the egg parasitoid *Trissolcus urichi* (Hymenoptera: Platygastroidea). In the first case, biological information of *N. edessae* is practically lacking while *T. urichi* is an important parasitoid of various pentatomids but little is known about its ability to attack *E. meditabunda* eggs. Regarding *N. edessae*, we found that on average, it parasitized ca. 70% of offered hosts, equally distributed between host sexes ($n = 102$; $c^2 = 0.023$; $p = 0.88$; $df = 1$). Moreover, the tachinid significantly reduced the longevity ($F = 20.25$; $df = 1$; $p > 0.001$), fecundity ($F = 11.23$; $df = 1$; $p = 0.001$) and fertility ($c^2 = 7.32$; $df = 1$; $p = 0.007$) of parasitized *E. meditabunda*. On its turn, *T. urichi* parasitism rate was assessed by offering 10 egg masses of *E. meditabunda* to a mated female one at a time every two days ($n = 44$). This parasitoid reached 87% of egg masses (and 84% of total eggs) parasitized. Besides, the offspring sex ratio was biased towards the females and the progeny's ♀ proportion per parasitized egg mass was 0.738, with no effect of the accumulated number of parasitized eggs by the parental wasp. The findings are promissory for the design of biocontrol programs to manage *E. meditabunda*, based on the use of *N. edessae* and *T. urichi* parasitoids, alone or in combination.

Session 2-P2 - Biological control and the agroecology toolkit

Mixture of *Btk* and the granulovirus CpGV reduces codling moth control

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In perennial crops such as apple orchards, several pests may be found in the same space at the same time. To control coexisting pests, a mixture of products in the spray tank could optimize applications. In Quebec, Canada, two major pests are found in the orchard at the same time during the summer. A different proportion of the populations of these two pests are found in the larval stage, a suitable stage for the use of ingestion bioinsecticides. Two biological control agents could be used in a mixture when spraying the crop. The granulosis virus, CpGV and the bacterium *Bacillus thuringiensis* subsp. *kurstaki* (*Btk*) are the most used bioinsecticides to control, the codling moth, *Cydia pomonella* and the obliquebanded leafroller pest *Choristoneura rosaceana*, respectively. In the laboratory, we evaluated these two bioinsecticides individually and in mixtures on the mortality of codling moth neonates. CpGV mixed with *Btk* was tested using concentration equivalent to field rate on codling moth neonates deposited on treated artificial diet. Mortality was estimated seven days post-application. Total mortality, which includes mortality that is virus-induced and due to unknown causes, was significantly higher in the CpGV treatment than in *Btk* and CpGV + *Btk* treatments. Alternatively, when considering only virus-induced mortality, the value was significantly higher in CpGV alone than in the CpGV + *Btk* mixture. The mortality reduction of neonates observed with the mixture could have a negative impact on codling moth population for neonates ingesting both bioinsecticides but not for those ingesting only the virus granules. However, the impact would be minimum, because mixed bioinsecticides caused 94% of neonate mortality, compared to 100% when CpGV was applied alone.

Session 2-P3 - Biological control and the agroecology toolkit

Maize direct response to entomopathogenic nematodes

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Interactions across multiple trophic levels, which include plants, herbivores, and herbivore natural enemies, play a crucial role in shaping ecosystem functionality and biodiversity. Despite extensive research on these interactions, it remains uncertain whether plants can directly perceive and react to herbivore enemies. In this study, we investigated how maize plants react, both locally and systemically, to the presence of entomopathogenic nematodes (EPNs) in the soil. EPNs are used in biological control to manage various insect pests, including the western corn rootworm (WCR), one of the main pests affecting maize production. By integrating metabolomics and transcriptomics analyses, we found that maize plants respond to EPNs, leading to alterations in the primary metabolism within leaves and roots. Notably, the profiles of soluble sugars exhibited changes in plants exposed to EPNs. Our findings underscore the importance of understanding these complex interactions in the development of effective and environmentally friendly pest management strategies.

Session 2-P4 - Biological control and the agroecology toolkit

Evaluating biorational products effects on twospotted spider mite and predatory mites under high tunnels-simulated conditions

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High tunnels (HT) are a protected agriculture tool for specialty crop farmers. Cucumbers (*Cucumis sativa* L.) are well suited for HT production because their vertical growth pattern allows for space optimization and repeated flowering, offering multiple harvest opportunities. However, the twospotted spider mite (*Tetranychus urticae* Koch; TSSM) is one of the primary pests of cucumbers in HT systems. TSSM often goes unnoticed by farmers until the damage is irreversible and the pest is difficult to control. Current recommendations are based on field or greenhouse production and rely on conventional miticides. However, more is needed to satisfy HT growers who wish to use organic pest management methods. Selecting the most efficacious and economical control methods for TSSM management in HT growing systems is difficult for growers because of the need for research-based evaluations in these unique growing environments. Here, we will present results from bioassays under laboratory conditions—first, the evaluation of the oviposition deterrence effect of the biorational products on TSSM. Second, assessing the mortality effect of the biorational products on TSSM adults and nymph. Lastly, the evaluation of the mortality effect on predatory mites (*Amblyseius andersoni*, *Neoseiulus californicus*, *N. cucumeris*, *N. fallacis*, and *Phytoseiulus persimilis*). The information gained through this work can help growers select biorational products that reduce TSSM populations and minimize the negative effects on predatory mites.

Session 3-P1 - Applied biological control in Latin America

Insectarios SRL: the first biological control supplier in Argentina

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Insectarios SRL was the first company in Argentina to produce beneficial insects. Founded in 1996, it began rearing the house fly parasitoid, *Spalangia endius.* At present, our main customers include feedlots, dairies, chicken layers, pig houses, and food industries. During the last season (September-April), the company produced 250 l/day of parasitized house fly pupae, delivering weekly applications to 90 customers' facilities. Favored by the implementation of innovative and simple management practices and by the prevalence of *Musca domestica* as the primary fly of importance, such parasite releases were very successful in reducing the fly population, showing a drop of up to 13 times, as monitored by spot cards. Field parasitization is regularly monitored through fly pupae bag traps. The proven effectiveness of the program, involving mass use and release of house fly pupae parasites, has significantly boosted growers' confidence in the benefits of this technique. The academic experience reached with IAEA, USDA, CSIRO, and the School of Agriculture of the University of Buenos Aires provided the expertise needed to carry out this project. The initial stages posed a significant challenge due to the absence of regulations, deep-rooted traditions in chemical control, a lack of advocacy for biological control, and the prevailing commercial isolation. www.insectarios.com.ar

Session 3-P2 - Applied biological control in Latin America

Evaluation of the antagonistic activity of *Trichoderma* spp. versus *M. roreri* in the Ecuadorian Amazon

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In Ecuador, cocoa is produced, with the highest production concentrated in the coastal and Amazon regions. Moniliasis is one of the most destructive diseases affecting cocoa. The severity of the pathogen's attack varies depending on the region, time of year, and climatic conditions, with losses reaching up to 60%. In this study, three native strains of *Trichoderma* from the Ecuadorian Amazon were used, and their antagonistic capacity against *Moniliophthora roreri* was evaluated *in vitro*. The percentage of radial growth inhibition was measured using the dual-culture technique and volatile metabolite tests in potato dextrose agar and V8 medium. Additionally, *Trichoderma* strains were preserved in rice for field evaluation to validate their potential in moniliasis control. Two bioformulations were developed based on isolates that showed the best results in *in vitro* tests under a completely randomized design. Cocoa trees underwent five treatments and were evaluated alongside a control in the field. The treatments included bioformulations: two native strains, two commercial strains, and a chemical copper treatment. All cocoa crops were subjected to the same management and environmental conditions. Variables assessed included the percentage of pods infected with moniliasis and the technical efficacy of treatments. Analysis of variance showed significant differences between treatments. The best *in vitro* results for *Trichoderma* spp. on *M. roreri* were obtained with isolates UEA-Th1 (*T. harzianum*) and UEA-Tv3 (*T. viride*). The chemical treatment yielded the best results for both the percentage of infected pods and technical efficacy. Among the biological treatments, the bioformulation UEA-T3 showed the best results and could be an alternative for controlling the phytopathogen *M. roreri*.

Session 3-P3 - Applied biological control in Latin America

Pathogenicity of four native isolates of *Beauveria bassiana* ((Balsamo) Vuillemin) against adults of *Metamasius hemipterus* L. in Pastaza, Ecuador

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Insect pathogenic fungi of the genus *Beauveria* are among the most important natural enemies of insect pests, including many species of Coleoptera. The native strains of this fungus perform an important role in natural control. However, its effectiveness in controlling the sugarcane weevil *Metamasius hemipterus* under conditions in the Ecuadorian Amazon is unknown. For this reason, this study aimed to evaluate the pathogenicity of four native isolates of *Beauveria bassiana* from the coffee borer in the control of adults of the weevil *M. hemipterus* under laboratory conditions. A completely randomized design was used with six treatments and five repetitions. The treatments evaluated were four isolates of *B. bassiana* (T1: BCP01, T2: BTHO01, T3: BTHO02, T4: BET01; applied at a concentration of 1 x 108 conidia.mL-1), T5: Engeo ® chemical insecticide (Thiamethoxam + lambdacyalothrin; at a dose of 1 mL.L-1) and T6: Control (Water + 0.1% Tween 80). The application of the treatments was carried out by immersion of the insects for 30 seconds. Mortality assessment was recorded daily after application. The Abbott formula was used to correct mortality. The data were processed by ANOVA, the comparison of means was performed with the Tukey test ($P < 0.05$). The native isolates of *B. bassiana* BTHO01, BTHO02 and BCP01 caused corrected mortalities of 100, 100 and 96% respectively, 8 days after inoculation. The first two isolates were significantly superior to isolate BET01. This study demonstrates that native isolates of *B. bassiana* are highly pathogenic against adults of *M. hemipterus* and constitute potential agents for use in the biological control of this pest insect in sugarcane cultivation in the conditions of the Ecuadorian Amazon.

Virulence of entomopathogenic fungi to *Disonycha glabrata* (Fabricius, 1775) (Chrysomelidae: Alticinae)

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Cows are insects from the Chrysomelidae Family with great diversity and wide distribution on the American continent. Most species are oligophagous or polyphagous and have many cultivated plants among their hosts. The genus *Disonycha* is still little known. The objective was to evaluate the entomopathogenic fungi *Beauveria bassiana* (Bals.) Vuill. (Boverril®) and *Metarhizium anisopliae* (Metsch.) Sorok. (Metarril®) in the control of *Disonycha glabrata*. Adult insects were obtained in the laboratory and bioassays were carried out with suspensions of conidia in sterilized distilled water containing 0.01% Tween 80 1.0 x 10^6; 1.0 x 10^7; 1.0 x 10^8 and 1.0 × 10^9 conidia.mL-1, in addition to the control (distilled water + 0.01% Tween) to evaluate the pathogenicity, virulence and production of conidia in insect corpses. For each isolate, 10 replications were used, with fifteen insects. Sterilized filter paper was placed on the plates and cotton was moistened with a guanxuma leaf underneath (*Sida rhombifolia*). The leaf was sprayed with 1 mL of the suspension from each treatment. Mortality was checked daily. The data were subjected to analysis of variance using the Scott-Knott test ($p \leq 0.05$). Insects killed by *M. anisopliae* and *B. bassiana* were placed in individual Petri dishes, kept in BOD at 26 ± 1°C and RH of 80 ± 10%, examined daily to evaluate the presence of mycelium and sporulation. The two fungi proved to be efficient as they promoted high mortality (average of 78.6%) in the first four days after inoculation. *M. anisopliae* showed a greater capacity to sporulate on cow corpses, being more pathogenic (mortality of 87.8% and virulent (TL_{50} = 1.6 days) followed by the fungus *B. bassiana* which caused 79% mortality in the first three days after inoculation. *B. bassiana* and *M. anisopliae* were shown to be pathogenic to adults of *Disonycha glabrata,* being promising microbial control agents for this pest.

Session 3-P5 - Applied biological control in Latin America

Study and identification of mites of the Phytoseiidae family using computer applications

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The diagnosis of predatory mites is the basis for establishing adequate biological control of the phytophagous prey of these mites. This work presents a website that contains updated information on mites of the Phytoseiidae family, which favors a quick and effective diagnosis of them. The site allows viewing the most recent results in the taxonomy and management of these mites, stimulates the carrying out of biological inventories and the formation of a system of complementary biological collections in taxonomic coverage. It also contains a digital key that facilitates quick identification of these mites. Both applications allow new information technologies to be incorporated into research and undergraduate and postgraduate study plans, which encourages the training and updating of teachers, researchers and students. The site was created using Macromedia DreamWeaver8 and the digital key was implemented in Borland C++ Builder. Both tools have been validated by students from the Agrarian University of Havana, researchers from the National Center for Animal and Plant Health and the Plant Health Research Institute.

Session 3-P6 - Applied biological control in Latin America

Has *Cephalonomia stephanoderis*, an introduced parasitoid of CBB, become very abundant almost 10 years after its release in Puerto Rico?

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The coffee berry borer (CBB), *Hypothenemus hampei,* is a pest that affects the yield of coffee growers in many, if not most, of the coffee-growing countries. Due to the life cycle and preferred habitat of the *H. hampei*, it not only represents yield loss but also proves to be quite difficult to manage without affecting the properties of the coffee the grower is producing, particularly for the growers who to grow their crops using the minimum or no pesticides. As such, using biological control agents like parasitoid in a classical augmentative release or as part of IPM strategies seems to be an eco-friendly solution. Like in many countries, *H. hampei* became a major pest for Puerto Rican coffee since its arrival in 2007. This led to past and present efforts to introduce some *H. hampei* natural enemies including parasitoids. Among those, *Cephalonomia stephanoderis* was introduced, and a colony established in Adjuntas Agricultural Experiment Station (AAES) in the early 2010s, followed by subsequent field releases. In 2014, Gallardo FE and its team reported that around 8% of CBB were parasitized by *C. stephanoderis* at sites sampled. We are presently working towards the introduction of *Phymasticus coffea*; as part of that effort, we have started to monitor the abundance of *C. stephanotis* in the coffee field we are studying for releases of *P. coffea*. The goals are to: (i) determine whether *Cephalonomia* is present and its abundance per site almost 10 years after its release? (ii) Is the number of coffee grains affected by *H. hampei* higher or lower in the sites where *C. stephanoderis* is still present? Monthly, we collect coffee grains at 5 coffee fields which are later dissected to determine the presence and abundance of *C. stephanoderis*. Also, randomly count the number of coffee berries per branch on 30 branches and determine the number of *H. hampei*-affected berries per developmental stage. Early results showed that if *C. stephanoderis* is present it is at very low abundance.

Session 3-P7 - Biological control and the agroecology toolkit

Lippia alba hydrosol in the control of *Fusarium* spp. in papaya

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Fusarium disease is caused by long *Fusarium* spp., and is considered one of the main diseases that affect papaya cultivation, causing significant fruit losses. Before this, the search for methods of controlling phytopathogens that are effective, safe and sustainable has awakened the interest of the scientific community, increasing the search for alternative control agents such as essential oils and hydrosols, for example. This is due to its antimicrobial properties and its potential to control diseases in plants and fruits. This study aimed to determine the minimum inhibitory and fungicidal concentration, as well as how to evaluate the percentage of inhibition of germination of the phytopathogen *Fusarium* spp. through exposure to different concentrations of *Lippia alba* hydrolate. The minimum inhibitory concentration (MIC) was carried out using the modified microdilution technique. Initially, 50 µL of *Fusarium* spp. spore suspension was added to each well of the microdilution plates at a concentration of 1x106 spurs.mL-1. Subsequently, 100 µL of each concentration (90, 80, 70, 60, 50, 40, 30 and 20%) were added to the wells. As a negative control, Papa Dextrosa cultivation medium was inoculated without the addition of hydrolate, and as a positive control, the antifungal ciclopirox olamine (400 µL.mL-1) was used. The experiment was carried out in quintuplicate with five repetitions. The test was carried out after 72 hours of incubation at 27°C, where the growth of the virus was visually observed in comparison with the control and the MIC was determined as the lowest concentration capable of inhibiting the growth of the microorganism. To determine the minimum fungicide concentration (CFM), a 10 µL aliquot is extracted from the pots containing *Fusarium* spp. It was not visible and subculture was carried out in Petri dishes containing PDA medium. The plates were incubated for 48 h at 27°C and CFM was considered the lowest concentration of *Lippia alba* hydrolate capable of causing death. The evaluation of the germination of the spurs occurred after 16 hours of incubation in the microdilution plate, the process was carried out using a drop of lactoglycerol and was carried out by randomly counting the germinated and non-germinated spurs, recording a total of 100 spurs. The MIC was observed at a concentration of 50%, while the CFM was 70%. Starting from a concentration of 20% of hydrolate, all tested concentrations demonstrated effectiveness in inhibiting more than 50% of the germination of *Fusarium* spp. spurs, highlighting the potential of *L. alba* hydrosol as a control agent. *Lippia alba* hydrosol has potential as a control agent against the phytopathogen *Fusarium* spp. suggesting that it can be used as a promising in the control of fusariosis in papaya, and can contribute to integrated disease management strategies in organic agricultural systems.

Keywords: antifungal activity, Carica papaya, medicinal plant.

Session 3-P8 - Biological control and the agroecology toolkit

Hydrosol potential of *Mimosa verrucosa* benth leaves in the control of *Aspergillus welwitschiae*

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The cultivation of sisal (*Agave sisalana* Perrine) is one of the most important crops for the semi-arid northeastern region, as it drives the economy, due to the extraction and commercialization of plant fibers from sisal leaves. However, this crop suffers from major production losses due to the occurrence of red rot, a disease caused by the fungus *Aspergillus welwitschiae*. As it is a disease that is difficult to control, it is necessary to seek effective and safe inovation, using active compounds, extracted from plants, such as hydrosol. Therefore, the objective of this work was to evaluate the potential of hydrosol from *M. verrucosa* leaves in controlling *A. welwitschae*. The extraction of the O.E. was carried out at the Phytochemistry Laboratory, at the Federal University of Recôncavo da Bahia, using the hydrodistillation method on Clevenger equipment. After completion of the process, the hydrosol was removed and stored until use. Using the agar diffusion technique, the hydrolate was mixed with the BDA medium (potato-dextrose-agar) at concentrations of 45, 60, 75 and 90% and two controls, BDA and BDA with antifungal (Ciclopirox de Olamine). After solidification, an aliquot of suspension containing the fungal spores was added. After this process, the plates were incubated in B.O.D and at the end of the experiment the number of spores was evaluated. The design adopted was completely randomized. Statistical analysis was carried out with the aid of the R program. The production of *A. welwitschiae* spores was significantly inhibited ($p < 0.05$) by the hydrosol, where the 45% concentration provided an increase in spore production, not differing from the concentration 0 (control), and the 90% concentration provided the greatest reduction in the number of spores. These results indicate that the hydrosol from *M. verrucosa* leaves has great potential to be used to control red rot in sisal.

Keywords: jurema rosa, bioproduct, red rot.

Session 4-P1 - Free session

Lessons learned: successes, limitations, and opportunities for classical biological control in the Southern U.S.A. (Tennessee)

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Classical biological control, or the introduction of natural enemies from other countries to new locations, has been a successful integrated pest management tactic against insects and weeds in numerous ecosystems throughout the world. In the state of Tennessee, which is located in the Southern Appalachians in the United States, classical biological control activities also have been implemented with varying levels of success. These include projects directed at weeds (such as musk thistle and spotted knapweed) and insects (such as hemlock woolly adelgid, emerald ash borer, crapemyrtle bark scale, and kudzu bug). Biological control of musk thistle, spotted knapweed, and kudzu bug have been highly successful, while those directed at hemlock woolly adelgid have been moderately successful. Other projects (such as those against emerald ash borer and crapemyrtle bark scale) are in their infancy and cannot be fully evaluated yet. Other researchers in Tennessee have implemented biological control programs against imported fire ant, Japanese beetle, cereal leaf beetle, alfalfa weevil, and euonmyous scale with varying levels of success. With the current concern about pesticide contamination, pesticide resistance, and environmental pollution, classical biological control will remain a viable option for consideration in management programs. In Tennessee, several new invasive species (brown marmorated stink bug and spotted lanternfly) have recently established, and several more species (Asian longhorned beetle and spongy moth) are on the horizon. Thus, plans to address these invasive pests before they become well established, widespread, and problematic are essential. Lessons learned from previous biological control programs highlight successes and limitations; these lessons can enhance activities directed against these new species to lessen their impact and expand opportunities for biological control. Funding and personnel must become available for initial biological control programs, as well as follow-up research to assess establishment, spread, and impact. This poster addresses ongoing classical biological control programs in this part of the United States (Tennessee) with emphasis on the importance of future programs.

Session 4-P3 - Free session

Evaluating predatory mites for the control of *Scirtothrips* in strawberry; from the lab to the field

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Thrips are key pests of horticultural crops around the world. Strawberries are typically attacked by the western flower thrips *Frankliniella occidentalis*, and in recent years in warm regions by *Scirtothrips* species, which feed and damage the immature developing leaf tissue. In the Canary Islands (Spain) the polyphagous *Scirtothrips inermis* has been causing severe damage to strawberry plantations. Here, we evaluated different biocontrol agents against *Scirtothrips* in laboratory and semi-field conditions, ultimately testing the effectiveness of different strategies in an open greenhouse.

Amblyseius swirskii, Amblydromalus limonicus, Transeius montdorensis, and *Neoseiulus cucumeris* all successfully preyed and laid eggs when feeding on larvae of *S. inermis* and *Scirtothrips dorsalis* in the laboratory. *A. swirskii* and *A. limonicus* were the most voracious species, and laid the highest number of eggs. In a semi-field cage trial, predators were released preventively and fed with *Artemia* cysts before the introduction of *S. inermis*. All predatory mites significantly reduced the population growth of *S. inermis* compared to the control, with *A. swirskii* and *A. limonicus* achieving the highest population growth and strongest pest suppression.

In an open-field greenhouse, the effectiveness of *A. swirskii* and *N. cucumeris* released through slow-release sachets was compared to an untreated control. Mite sachet densities were matched in cost, and sachets were released continuously every four weeks. Both mite species effectively suppressed the natural infestation of *F. occidentalis* and *S. inermis*. Densities of *N. cucumeris* were higher than those of *A. swirskii* in the winter, but the reverse was found during spring and summer.

Session 4-P4 - Free session

Oviposition determinants in *Istocheta aldrichi* (Diptera: Tachinidae), a parasitoid of the Japanese beetle

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Istocheta aldrichi (Diptera: Tachinidae), a parasitic fly specific to the Japanese beetle, *Popillia japonica* (Coleoptera: Scarabaeidae), was introduced to North America from Japan in the 1920s as part of a large biological control program. Very little information has been published on *I. aldrichi* since its introduction, but there is currently a regain of interest because this biological control agent is expanding its range naturally and through redistribution releases in newly areas invaded by the Japanese beetle in USA and Canada. Furthermore, the Japanese beetle has started to invade areas in Europe where *I. aldrichi* is now considered for release. This study is part of a larger research program designed to characterize the biology of *I. aldrichi* and evaluate its population-level impact on Japanese beetle populations. The main objective was to determine the extent to which host sex, size, density, and defensive behaviour might influence oviposition decisions in *I. aldrichi*. Using field-captured Japanese beetles, over a five-year period (2018–2022) in Québec, Canada, we showed that: (i) there is strong bias toward female Japanese beetles being more parasitized than males, (ii) parasitoid females more readily attack large hosts, both males and females, than small hosts, and (iii) host density-dependent parasitism rates vary throughout the season. Oviposition success in *I. aldrichi* is also shaped by the mating and defensive behaviors of the Japanese beetle; oviposition usually takes place upon mating pairs and being immobilized during copulation females cannot achieve the typical defensive behavior they use when attacked by a natural enemy. Egg-laying decisions by *I. istocheta* females are shaped by trade-offs between host suitability, seasonal abundance, and defensive behavior.

Session 4-P5 - Free session

Field monitoring of houseflies and their parasitoids in dairy farms in Northern Italy

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The housefly *Musca domestica* is a common pest in livestock farms. A monitoring activity was conducted on six dairy cattle farms in Reggio Emilia, Northern Italy, from June to September 2021-2023. The farms were divided according to their fly management practices, either organic (release of pupal parasitoids) or conventional (chemical treatments). The aim of the monitoring activities was to assess the impact of various factors on the biological control of *Musca domestica*, specifically in relation to fly management techniques (release of parasitoids versus chemical treatment). The study analyzed the activity and relative abundance of houseflies and their pupal parasitoids in two zones of each farm: the calves' area and the dunghill area. In addition, differences in species abundance between farms with different management practices were compared. To monitor flies, rolling sticky traps were placed in each farm and zone and replaced weekly. To determine the activity and abundance of pupal parasitoids, at least 40 pupae were collected weekly from the designated zones, if possible. No differences were found in the number of flies captured and the proportion of specimens (houseflies and pupal parasitoids) between the farms in terms of management type. However, differences were detected between farms. The genus *Muscidifurax* was the dominant parasitoid in organic farms, with the species released in these farms belonging to this genus. In conventional farms, however, the dominant genus was *Spalangia* sp., with some exceptions. For instance, in organic farm B3, the *Spalangia* genus was more abundant than in the other organic farms but similar to conventional farms. Based on the monitoring results, it is suggested that in order to reduce the housefly infestation to an acceptable level, it is important to consider environmental parameters, cleaning practices, and the management of different zones on individual farms, as well as the use of mass traps for flies.

Session 4-P6 - Free session

Taxonomic and genomic diversity of a worldwide collection of entomopathogenic fungi

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Between 1987–2003 a large worldwide collection of entomopathogenic fungi was collected and preserved. The collection contains approximately 1000 strains and was initially characterized by morphological characters. Draft genome sequencing of the strains has been completed and the results made publicly available. The collection contained more than 33 species of entomopathogenic fungi, with the three most common species being *Beauveria bassiana, Cordyceps javanica* and *Beauveria pseudobassiana.* The dataset provides a comprehensive view of the genomic diversity of these important biocontrol species. The genomes will help identify the genetic determinants of host specificity and the evolutionary pressures on these species. In addition, the genomes allow us to explore the secondary metabolite diversity of these biopesticides.

Session 4-P7 - Free session

First detection of the broad-nosed knapweed seed head weevil, *Bangasternus fausti* (Coleoptera: Curculionidae) in Canada

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The broad-nosed knapweed seed head weevil, *Bangasternus fausti* (Reitter, 1890), is a palearctic species that has been introduced to the western United States for biological control of invasive diffuse and spotted knapweed (*Centaurea diffusa* Lam. and *C. stoebe* ssp. *micranthos* (Gugler) Hayek: Asteraceae) (Smith & Mayer 2005; Winston *et al.* 2012). It established in both Oregon and Montana after releases began in 1990 (Lang *et al.* 2000; Smith & Mayer 2005), and it has since been released in or redistributed to Washington, Idaho, and areas of the southwestern USA (Winston *et al.* 2014). *Bangasternus orientalis* (Capiomont, 1873), a palearctic congeneric of *B. fausti*, has also become established in the western USA following biocontrol releases on invasive yellow starthistle (*Centaurea solstitialis* L.) (Winston *et al.* 2014). Neither species of *Bangasternus* are known to occur in Canada (Bousquet *et al.* 2013), nor have they been approved for biocontrol releases in Canada (Winston *et al.* 2014). However, there are now several dozen observations of *Bangasternus* spp. in the southern interior of British Columbia, Canada reported via iNaturalist.org, suggesting that one or both of these species have moved northward from the USA. Here, we surveyed the southern interior of British Columbia for *Bangasternus* species. Using a combination of insect taxonomy – specifically diagnostic male genitalic morphology, molecular diagnostics - cytochrome *c* oxidase subunit I (COI) DNA barcoding, and host-plant association, we provide evidence that the broad-nosed knapweed seed head weevil, *Bangasternus fausti* is now established in southern British Columbia, Canada. We discuss its potential role in providing suppression of diffuse knapweed and its possible interactions with the existing seed head feeding biocontrol agent community.

Session 4-P8 - Free session

Isolation of endophytic fungi in Cuernavaca, Morelos for the control of rust (*Hemileia vastatrix*) in coffee cultivation

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In Mexico, approximately 712,015 ha of coffee have been established, distributed in 482 municipalities of 14 federal entities of the country, such as Chiapas, Veracruz, Oaxaca, Puebla and Guerrero, which together concentrate approximately 91% of the area established in Mexico since Coffee is susceptible to pests and diseases, among which are the coffee borer (*Hypothenemus hampei*) and coffee rust (*Hemileia vastatrix*), detected for the first time in Mexico in the Soconusco region, Chiapas 1981, taking into consideration the degree of affectation of coffee rust, as well as the importance of generating a biological control alternative for organic coffee producers, the objective of this research was to isolate endophytic fungi in coffee crops so that they are capable of controlling rust. of coffee (*Hemileia vastatrix*) under *in vitro* and *in vivo* conditions, first the search for endophytes was carried out in Cuernavaca, Morelos in coffee plantations approximately 6 years old, samples of mycosed leaves were taken and subsequently transferred to the bioinsecticide laboratory of the UAEM, where the morphological characterization was carried out, where the hyphae, conidia, and their development were observed according to the morphological tests, isolates of *Akanthomyces* spp were obtained, the samples are kept in conservation in sterile water and silica gel, this with the in order to maintain the biological material in optimal conditions, to later compare its effectiveness with methods currently used, to determine if there are more alternatives to support the biological control of the disease.

Session 6-P1 - Molecular tools in biological control

Phytochemical composition of *Commiphora* oleogum resins with insecticidal activities

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Oleogum resins of genus *Commiphora* are being valued in traditional medicines for its anti-bacterial, anti-fungal, anti-parasitic, and even COVID-19 activities. In addition, *Commiphora* extract and its essential oil exhibit larvicidal activity against mosquitos and other insects such as cotton leafworm. *Commiphora* species, that grow mainly in Africa and the Arabian Peninsula, are known to exhibit highly variable phytochemical compositions. The aim of the study was to compare the chemical composition of *Commiphora* oleogum resins of the species *C. myrrha, C. erythraea, C. mukul, C. holtziana, C. confusa*, and *C. kua*, as well as unspecified *Commiphora* resins from Ogaden (Ethiopia) and Tarraxo regions. A novel highly selective, sensitive, accurate HPLC-MS/MS method was developed and validated to quantify five characteristic phytosteroids and furanosesquiterpenoids, namely (*E*)-guggulsterone, (*Z*)-guggulsterone, curzerenone, furanoeudesma-1,3-diene, and myrrhone. *Commiphora* essential oils were obtained by hydrodistillation of the respective oleogum resins. The hydrodistillation yielded from 0.06% (w/w) essential oil in *C. kua* till 4.2% (w/w) essential oil in *C. confusa*. However, by hydrodistillation of the *Commiphora* oleogum resin from Tarraxo, no essential oil could be obtained despite of an exhaustive distillation process. Chemical composition of *Commiphora* oleogum resin essential oils was quantified by gas chromatography and flame ionization detection (GC-FID) using internal normalization. The resulting contents were used to classify and differentiate *Commiphora* oleogum resins of the species analyzed. Interestingly, a *Commiphora* sample from Ogaden comprised guggulsterones, which is presumed to be unique to *C. mukul* from the Indian subcontinent. However, *Commiphora* from Ogaden differed considerably from *C. mukul* in respect to guggulsterones isomer´s ratio. This study could aid identification of *Commiphora* botanical extracts with enhanced medicinal and insecticidal activity.

Session 7-P1 - Pre-emptive classical biological biocontrol

Estimation of the global biocontrol potential of two native parasitoids *Chelonus insularis* and *Eiphosoma laphygmae* against the fall armyworm

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The fall armyworm (FAW) causes enormous damage to crops. *Chelonus insularis* and *Eiphosoma laphygmae* are promising biocontrol agents of FAW. By integrating species distribution models and hotspot analysis, this study assessed the optimal areas for controlling FAW with these two parasitoids worldwide. Key variables influencing distribution include human influence index, temperature, and precipitation. The optimal control areas with *C. insularis* are in southern North America, South America, and Africa. *Eiphosoma laphygmae* is effective in southern North America, South America, central Africa, and southern and southeastern Asia. These areas are expected to expand to high-latitude areas under changing climatic conditions. Niche comparisons indicated that the FAW and *C. insularis* niches were closely aligned. *Chelonus insularis* and *E. laphygmae* are potentially effective against FAW in Africa and Asia, respectively. Our findings offer insights into the strategic use of the two parasitoids against FAW worldwide.

Session 8-P1 - Use and preservation of parasitoids in agriculture

Use of egg parasitoids in fall armyworm *Spodoptera frugiperda* augmentative biological control: challenges and opportunities

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The fall armyworm (FAW) (*Spodoptera frugiperda*) is a transboundary insect pest with high potential for rapid dispersal due to its natural ability to spread, its polyphagous habit and a remarkable ability to develop resistance to insecticides. As a side effect, this adaptability can cause unprecedented impacts to agriculture, especially to maize (*Zea mays*) if not managed properly. Currently, the control of this pest is carried out predominantly with synthetic insecticides although the use of biological control agents constitutes an important, sustainable and efficient tool within integrated pest management (IPM). Among different biocontrol agents, egg parasitoids have been highlighted in ABC for their following advantages: (i) they can be reared in large numbers in small spaces, (ii) they control pests in their first stage of development (egg), before any injury to plants is caused, (iii) they are effective against different pests and relatively safe to non-target organisms. Among the different natural enemies reported for FAW, the egg parasitoids *Telenomus remus* and *Trichogramma* spp. are the most studied and used species, both showing great potential for augmentative biological control (ABC) of FAW and other armyworms that often attack maize. In this context, a new strategy of performing releases of combined parasitoid species is introduced and the benefits of releasing fed adults inside capsules instead of pupae close to emergence are a new approach in the use of both parasitoids.

Session 8-P2 - Use and preservation of parasitoids in agriculture

Euschistus heros egg parasitoids: effect of host egg age and collection site

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In Brazil, the soybean crop has *Euschistus heros* F (Heteroptera: Pentatomidae) as the main pest, responsible for severe economic damages every year. As an alternative for its control is recommended the release of parasitoids, which parasites the egg controlling her population. In this scenario, prospection studies are important for discovery of new parasitoid species aiming to expand the range for *E. heros* control. This study evaluated two different locations, a Cerrado fragment, and a sorghum field (*Sorghum bicolor* L. Moench), and three different egg ages (12, 24, and 48 hours). In both locations were placed 15 traps with 30 *E. heros* eggs, which are 5 replications from each age. The eggs were fixed with double-sided tape, the traps fixed by entomologic glue-dipped string for protection. Traps were exposed in the field for 48 hours, being collected and stored in test tubes (8,5 cm length, 2,5 cm diameter) with honey droplets and closed with polyethylene film. The tubes were kept in climate-controlled rooms at 25 ± 2°C and 60% ± 10 RH till the emergence of the parasitoid or *E. heros*. Regardless of the environment evaluated, average parasitism was low, mainly on forest area, which has presented an average parasitism of 0.74% regardless of host egg age. This environment has no egg age effect. The sorghum area has a higher average parasitism (8.06%), in all egg ages, the highest parasitism was obtained for the ages of 12 h and 24 h, being 12.0% and 10.4% respectively. In sorghum eggs aged 48 hours showed only 2.0% of average parasitism. The obtained parasitoids were separated into morphospecies of the families Scelionidae and Encyrtidae and sent for identification. Sorghum has presented a predation rate of 23.3% on average and a forest area of 7.40%, regardless of egg age. Results show that despite the low parasitism rate, in both environments, there was parasitoids for this pest. Future tests are necessary to understand the low rate of parasitism, to avoid the egg predation.

Session 8-P3 - Use and preservation of parasitoids in agriculture

Rearing optimization of *Callosobruchus maculatus*, an alternative host for boll weevil parasitoids

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The larval parasitoid *Jaliscoa grandis* (Hymenoptera: Pteromalidae) is an important natural enemy of the boll weevil. It can be reared using *Callosobruchus maculatus* (Coleoptera: Curculionidae) as an alternative host. This work aimed to evaluate different containers for host production to maximize the number of insects produced. The density of 1 insect host/1.5 g of black-eyed peas (*Vigna unguiculata*) was used. Three types of containers and different positions within the containers were tested. A tall pot (10 x 25 cm, base and height), a large box (30 x 30 cm), and a small box (7 x 7 cm) were evaluated. In the tall pot, 3 depths were evaluated (2, 9, and 16 cm). In the large box, two distances were evaluated (center and edge). In the tall pot and the large box, 1500 grams of beans and 1000 individuals were used; in the small box, 150 g of beans and 100 individuals. Oviposition was allowed for 5 days, after which the adults were removed, and the eggs were counted. Five replications were installed. Despite the same density of individuals per container, there was a difference in the average number of eggs between them. The large box had the highest average, being 4.4 eggs/grain, higher than the tall box (3.0 eggs/grain) and small box (2.9 eggs/grain), which did not differ from each other. A difference was observed between the depths inside the tall pot, being 5.0 eggs/grain at 2 cm (closest to the surface) and 1.7 eggs/grain at 16 cm (deepest). Inside the large box, there was also a difference: 6.3 eggs/grain in the center and 2.4 at the edge. The results indicate that there is a difference in the distribution of eggs both vertically and horizontally. On the other hand, in the small box, even if the same density was maintained and there was little space for insect dispersion, there were fewer eggs. These results do not allow us to conclude which container is the best among those tested, and further studies are needed.

Session 8-P4 - Use and preservation of parasitoids in agriculture

Is *Anastatus japonicus* an effective biological control agent against brown marmorated stink bug?

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The brown marmorated stink bug, *Halyomorpha halys* (Hemiptera: Pentatomidae), native to East Asia, has become an important economic insect pest worldwide since its invasion in the Americas and Europe. Egg parasitoid *Anastatus japonicus* (Hymenoptera: Eupelmidae) has been selected as a potential candidate for inundative biological control of *H. halys* in the area of origin. We hypothesized that *A. japonicus* continuously reared on a factitious host in the laboratory would not deteriorate its field performance against *H. halys*. Field release trials were conducted in kiwifruit orchards with release rate of 20,000 wasps per release per plot and four releases per plot. Sentinel *H. halys* eggs were exposed after each release to assess parasitism rate of *A. japonicus* as well as other reproductive attributes such as sex ratio. Although parasitism increased gradually after each release, overall parasitism rate was rather lower compared to parasitism obtained from laboratory bioassays. Sex ratio of *A. japonicus* progeny was male-biased. The different performance of *A. japonicus* might be attribute to degradation of rearing cultures, reduced searching ability, and ability to adapt to environmental conditions, which will be discussed in the context of inundative biological control.

Session 8-P5 - Use and preservation of parasitoids in agriculture

Nonreproductive effects are more important than parasitism in *Trichogramma* spp.?

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Egg parasitoids of the genus *Trichogramma* Westwood are among the most widely used and studied natural enemies in the world. Their efficiency is due to the mortality caused by their reproductive mechanism (parasitism). However, despite being less studied, there are other non-reproductive pathways that can also result in the death of the host, such as pseudoparasitism. This process occurs when females inject substances that alter the physiology of the host, but with no eggs laid. Usually, in studies with *Trichogramma*, eggs from factitious hosts are used, which are sterilized under germicidal lamp (to avoid the hatching larvae and cannibalism). However, to assess the pseudoparasitism, it is not possible to use sterilized eggs. Therefore, the aim of the study was to assess the potential control of the new species *Trichogramma foersteri* Takahashi compared to *Trichogramma pretiosum* Riley on eggs of *Anticarsia gemmatalis* Hübner and *Helicoverpa armigera* Hübner. The following biological aspects were assessed: i) number of parasitized eggs (darkened); ii) number of pseudoparasitized eggs (without progeny); and iii) total mortality (parasitism + pseudoparasitism). For *A. gemmatalis*, both parasitism and pseudoparasitism were higher in *T. foersteri*, with 169 and 240 eggs, respectively, compared to *T. pretiosum* (97 and 88 eggs). The total mortality observed for *T. foersteri* was 509 eggs, approximately 180% more than *T. pretiosum* (185 eggs). In *H. armigera*, *T. foersteri* also outperformed *T. pretiosum*, showing parasitism in 140 eggs and pseudoparasitism in 416 eggs, while *T. pretiosum* exhibited values of 36 and 104 eggs, respectively. The total mortality was 140 eggs for *T. pretiosum* and 557 for *T. foersteri* (300% more). It is concluded that pseudoparasitism should be evaluated alongside parasitism since it can significantly contribute to host mortality, and, in some cases, it may represent the major portion of mortality caused by the parasitoid.
São Paulo Advanced Research Center in Biological Control (SPARCBIO)-FAPESP-Koppert, process: 2018/02317-5.

Session 9-P1 - Biological control in a changing world!

A unique case of successful control of an invasive pest: self-introduced exotic parasitic wasps shifted attempted classical biocontrol to conservation biocontrol

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The invasive kudzu bug, *Megacopta cribraria* (Fabricius), made its debut in Georgia in the SA in 2009. It quickly spread with exponentially growing populations to become a major yield-loss pest of soybeans across the Southeastern States. Soybeans have a $124 billion impact on the US economy. Soybean farmers relied solely on pesticides to battle this pest. Researchers identified the exotic *Paratelenomus saccharalis* (Dodd) as the top egg parasitic wasp. After a one-year evaluation in USDA/Biological Control Quarantine Research Facility in 2012, researchers proposed field-release trials in July 2013. Surprisingly, one month before implementing the intended release, the same wasp was discovered in June 2013 in soybean fields in multiple states. Three years later, another nonnative egg-parasitic wasp, *Ooenyrtus nezarae* (Ishii), emerged in soybean fields. Both species showed astonishingly great egg parasitism rates of 5–90%. Furthermore, the wasps' occurrences in different states were simultaneous and followed the same sequential order with *P. saccharalis* emerging about 3 years after kudzu bug colonization and *O*. n*ezarae* about 6 years after colonization. The unanticipated wasps shifted the attempted classical biocontrol effort to a conservation biocontrol. IPM tactics and strategic pesticide application were practiced to protect non-native wasps and native predators. Kudzu bug populations declined, with sharp decrease curves occurring from 2014–2017, to a stable equilibrium with the pest populations remaining suppressed to about the economic threshold.

Session 10-P1 - Mechanism in conservation biological control

Effect of the extrafloral nectar of *Senna cernua* Balb. H.S. Irwin & Barneby (Fabaceae) on the survival of the coffee leaf miner parasitoid *Proacrias coffeae* Ihering (Hymenoptera: Eulophidae)

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The enhancement of pest control through the conservation of natural enemies in agricultural fields is called conservation biological control. One of the strategies used on this system is to introduce or manage plants that can provide food for natural enemies. We assessed the effect of feeding resources on the fitness of a coffee leaf miner parasitoid, *Proacrias coffeae* Ihering (Hymenoptera: Eulophidae), by evaluating the effect of extrafloral nectar of the leguminous shrub *Senna cernua* Balb. H.S. Irwin & Barneby on the survival of *P. coffeae*. The experimental unit consist in a clip cage (3 cm diameter) with one newly emerged *P. coffeae* female inside, placed in a part of the plant containing an extrafloral nectary and with the controls placed in a part of the plant without an extrafloral nectary. 23 parasitoids fed on the extrafloral nectar and 23 serve as controls. The parasitoids were observed daily to assess their survival. The survival of *P. coffeae* were estimated by a Kaplan-Meier survival analysis. The treatment was separately contrasted with its control. *Proacrias coffeae* adult females survived longer when feeding on extrafloral nectar from *S. cernua*, (24.22 ± 2.78 days) than in the control (6.34 ± 1.36 days) ($p < 0.0001$). Based on the research study, it is evident that the introduction of feeding resources *for P. coffeae* in the coffee agroecosystem will increase their fitness as a potential biocontrol agent.

Session 10-P2 - Mechanism in conservation biological control

Does a conservation biological control strategy modify the density dependent relationship between aphids and hoverflies?

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Relationships between density of prey and density of predators (i.e. the numerical response), or predation rate (i.e. the functional response) are of importance when implementing biocontrol strategies. Likely linked to the difficulty of measuring these relationships, they are often not tested whereas we always expect a positive relationship between number of prey and number of predators or number of prey eaten to make biological control operating. In addition, while conservation biological control strategies aim at improving biological control and thus strengthen the positive relationship expected between density of prey, of predators and number of prey eaten, the change of these relationships are often not formally studied and may change due to different factors such as aphid or host plant quality.

Syrphidae are among the earliest and the most efficient natural enemies of aphids in the spring, for instance, of the rosy apple aphid, a major pest of apple orchards. For these reasons, conservation biological control strategies rely principally on these species to control aphids, and the rosy apple aphid particularly. However, until now, few studies aimed specifically at describing the numerical and functional response of Syrphidae in presence of aphids, and particularly in presence of the rosy apple aphid. Moreover, contrasting results were found in the literature, some authors found density dependance response of Syrphidae (e.g. Dib *et al.* 2010) while other not (e.g. Minarro *et al.* 2004), potentially due to uncontrolled experiments.

We propose here to study the numerical and functional response of Syrphidae and study whether a biological control strategy, used to attract and retain natural enemies may modify these relationships. To do this, we will set up sentinel plants infested with different density of aphids in an experimental apple orchard including plots with and without biocontrol strategy implemented, and when Syrphidae are the only flying natural enemies.

Session 10-P3 - Mechanism in conservation biological control

Conservation practices for the enhance of predatory mites: opportunities and challenges

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Indiscriminate pesticide use has led to the elimination of important organisms in the agroecosystem that support crop production, mainly in developing countries where farmers and the environment are exposed to high levels of synthetic insecticides, including active ingredients that have been banned due to high toxicity and persistence. Biological control is a key strategy in an IPM program, and Neotropical area has a high potential for the application of biological control based on its rich biodiversity. Moreover, conservation biological control based on habitat manipulation has been proposed as a sustainable alternative involving intentionally establishing plant species at the farm scale or landscape scale to provide conducive habitats, floral resources and alternative prey at the right time and space to support natural enemy assemblages to promote biological pest suppression. The main habitat manipulations reported as conservation biological control include plant diversification (intercropping, agroforestry), conservation and management of non-crop vegetation, and application of artificial foods, however, in Latin America, the investigation is still scarce using predatory mites. Various challenges have been identified specifically related to how different agricultural practices and habitat manipulation in Latin America have influenced pest management through natural enemy conservation. Also, farmers' education is crucial to better understand on how to apply conservation biological control. Thus, more systematic studies are required to accurately evaluate the effects of habitat management to implement conservation biological control for pest control in Latin America. Here, we discuss on practices used in other countries around the world and the opportunities to be adapted in the Latin American context.

Session 10-P4 - Mechanism in conservation biological control

Entomopathogenic fungi in Eucalyptus plantation areas on the North coast of Bahia – Brazil

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Bioprospecting for entomopathogenic fungi can allow the location of specimens with great pathogenicity and virulence. Among biological control agents, entomopathogenic fungi can control insect infestations that harm production in the forestry sector. Control with microorganisms is one of the main components of integrated rule management, but is still little used in forest areas. The objective was to identify entomopathonic fungi associated with pest species in eucalyptus areas. The study was carried out in areas planted with *Eucalyptus* sp. belonging to the forest area of the municipalities of Aramari Inhambupe and Alagoinhas in the state of Bahia. The occurrence of fungi, results from live and dead insect pests found in the field. These were taken to the Agricultural Microbiology and Entomology laboratories at UFRB and the Isolation methodology was carried out. Live insects were kept in cages until death. The insects were then disinfected and placed individually in petri dishes in the environment. The isolates were then multiplied in BDA (Potato Dextrose Agar) culture medium, in B.O.D. incubator at 27°C ± 2°C and a 14-hour photophase, for 7 to 15 days, to allow conidiogenesis and confirm the causal agent of mortality. The fungi were then identified using conidia and conidiophores morphology and dichotomous keys. Forest pests collected were: *Costalimaita ferruginea* (Crysomelidae), *Thyrinteina arnobia*, *Euselasia apisaon*, *Glena* sp., *Eacles ducalis* and *Sarcina violacens* (Lepidopterae) and psyllids (Homopterae). The fungi identified to date are *Beauveria bassiana* (Bals.) Vuill., *Isaria fumosorosea* Wize, *Nomuraea rileyi* (Farlow) Samson, *Cordyceps* sp., *Verticillium lecanii* (Zimm.) Viégas, Whorl. sp. and *Paecilomyces* sp. The great diversity of entomopathogenic organisms highlights an apparent and inexhaustible source of bioinsecticides. The inclusion of the use of fungi will be a promising strategy for managing insects indirectly in reforestation areas.

Session 14-P1 - Raising awareness for action: Country perspective

Farmer biopesticide for fall armyworm management in Zambia

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Fall armyworm (FAW), *Spodoptera frugiperda*, is the most damaging invasive species in Zambia causing a great threat to food security and livelihoods. Management of FAW is largely carried out using conventional chemical pesticides. Excessive use of hazardous pesticides has impacts on food quality, natural environment and food safety. Objective of the research project was to develop a model for novel, affordable, sustainable, effective and locally adaptable production of baculoviruses (FAWLIGEN) at farm level to combat FAW. It was conducted in Ngwerere and Kasisi. Treatments were Emamectin benzoate, Icipe7, Fawligen, Farmers' biopesticide (crushed larvae) and control. Fawligen was sprayed every 7 days, virus ingested larvae were picked. 120 to 150 larvae were crushed and put into 16 l knapsack. Parameters were foliar damage, cob length, cob damage and grain yield (kg). After the third applications, noticeable reduction across the four treatments, except for the control where infestation increased with plant growth. From both sites, chemical treatment recorded less cob damage while control treatment recorded highest cob damage score. Yield ranged from 2.6 kg to 5.6 kg in Kasisi and 3.2 kg to 7.7 kg in Ngwerere site. In both sites, yields were higher in chemical and lowest in control.

Session 14-P3 - Raising awareness for action: Country perspective

Inspiring interest in insects – discovery through play

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Have you ever wondered why so few people are interested in insects? Our sizeist society seldom sees insects, especially the small ones as worthy of notice, and yet every insect is beautiful and has a fascinating story to tell.
Games are widely acknowledged as educational tools and are extensively used, yet few explore the rich world of entomology.
This poster displays a beautifully illustrated range of arthropod pests and beneficials (plus one fungus), featured as a card game, suitable for children and adults. It is a simple but powerful interactive experience that introduces players to the concept of biological control.
Calling out key characteristics and fascinating 'did you know' facts, the 36 cards feature many insects most people would otherwise never encounter. Of course the classic red ladybird (*Adalia bipunctata*) and a bumblebee (*Bombus terrestris*) feature, but there are also the blue Brazilian rain forest butterfly (*Morpho menelaus*), the green vegetable bug (*Nezara viridula*), the citrus mealybug (*Planococcus citri*), its parasitoid, *Anagyrus vladimiri* and a classic Phytoseiid.

Session 15-P1 - Improving biological control traits

Does parasitism in adult stages of female mealybugs prevent oviposition of the pest host? The case of citrus mealybug *Delottococcus aberiae* and its parasitoid *Anagyrus aberiae*

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Mealybugs are among the most frequent invasive species of crops and ornamental cultivars. Their cryptic behavior allows them to remain undetected, thereby multiplying their populations for long periods of time. One of the factors leading to a rapid increase and expansion of mealybug populations is the large number of eggs laid. Parasitoids of mealybug early stages kill their host before they start producing eggs, but for many species what happens when they parasitize late instars or female adult mealybugs remains unknown.

In this study, we present the case of *Anagyrus aberiae* (Hymenoptera: Encyrtidae), a parasitoid of female adult stages of the mealybug *Delottococcus aberiae* (Hemiptera: Pseudococcidae) and analyze the parasitoid capacity to prevent mealybug egg production and/or ovisac. For this purpose, we analyzed the number of eggs laid by parasitized mealybugs at three different moments of parasitization: before, after and three days after female mealybug mating with a male.

Results show that the three parasitism treatments significantly reduced the number of eggs and lifetime fecundity of the mealybug. Female mealybugs parasitized before mating also exhibited a decrease in oviposition compared with the post-mating parasitism treatments. Our results indicate that parasitoids of adult mealybug stages are indeed effective biocontrol agents and manage to reduce the egg load and oviposition of mealybugs.

Session 15-P2 - Improving biological control traits

Fine-scale mapping and comparative genomics link parasitoid *Nasonia host preference 1* to an odorant receptor-enriched region

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Host specificity, the parasitoid trait controlling generalist versus specialist use, determines ecological risk of non-target effects and efficacy against a specific pest. Despite its practical implications for biocontrol, little is known about the genetic architecture of parasitoid host specificity. In a previous study for *Nasonia* blowfly parasitoids, a 16MB region ($bkbw_g$) in chromosome 4 introgressed from the specialist *N. giraulti* into generalist *N. vitripennis* background induced a host preference switch. This region carries putative *host preference 1* (*hp1*) that is specialist dominant and additive. We used 15 indel markers and a new assay with commercial hosts to track retention or loss of specialist *hp1* in rare recombinants. We resized the original $bkbw_g$ region to 20.1MB and localized *hp1* to a 4.1MB region. We performed comparative functional analyses with the *N. vitripennis* and *N. giraulti* genomes. Genome annotations indicated that $bkbw_g$ is the most olfactory-receptor (OR) enriched region of *N. vitripennis*. Comparative orthology identified two genes unique to *N. giraulti* as the strongest candidates for *Nasonia hp1*. Further functional analyses are needed to pinpoint their role in host specificity.

Session 15-P3 - Improving biological control traits

Parasitization activity of *Spalangia cameroni* and *Muscidifurax zaraptor* (Hymenoptera, Pteromalidae), pupal parasitoids of *Musca domestica* (Diptera, Muscidae)

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Musca domestica Linnaeus (Diptera, Muscidae) is a major pest in livestock farms and a major concern for both humans and livestock due to its ability to transmit over 200 pathogens. The use of pupal parasitoids is a sustainable strategy to manage this pest. *Spalangia cameroni* Perkins and *Muscidifurax zaraptor* Girault & Sanders (Hymenoptera, Pteromalidae) are commonly used as biocontrol agents against *M. domestica.* The aim of this study was to determine the oviposition peak of female parasitoids in relation to their age and the sex ratio of newly emerged adults. For both species, 20 fresh *M. domestica* pupae (24-48h) were provided daily to each fertilised female for 14 days. The pupae were then checked for parasitoid emergence. A control group of 20 pupae without female parasitoids was also maintained. The study found that *S. cameroni* had a higher overall percentage of parasitisation (57.71%) compared to *M. zaraptor* (32.41%). The parasitisation rate of *S. cameroni* remained almost constant throughout the 14-day period, while that of *M. zaraptor* decreased drastically after the 11th day. *S. cameroni* had its peak oviposition on day 5 with 13 parasitised pupae, while *M. zaraptor* parasitised 8 pupae per day during its peak oviposition period (between days 3 and 8). The newly emerged parasitoids exhibited a skewed sex ratio towards females, with 81% for *S. cameroni* and 66% for *M. zaraptor*. The presence of these parasitoid species resulted in fewer new housefly emergences compared to the control group, where natural pupal mortality was lower in the absence of parasitoids. These findings could be invaluable in optimising the mass production and time-use of the two parasitoid species for effective biocontrol of houseflies on livestock farms.

Session 16-P1 - Biodiversity-based pest management practices

Landscape composition and heterogeneity, at different spatial scales, filters functional traits and modulate coccinellid communities in alfalfa

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Agricultural landscape composition and configuration, at different spatial scales, may act as environmental filters to the natural enemy traits related to biological control. Usually, landscape simplification drives biotic homogenization of traits in arthropods communities. Coccinellids are important biological control agents of aphids in alfalfa. Here we examine the effects of the composition and configuration of landscapes at different spatial scales on coccinellid communities in alfalfa, based on their functional traits, identifying functional response groups (syndromes). We sweep-sampled coccinellids in 40 alfalfa fields at two-weekly intervals in spring and summer 2020 and 2021, and characterized the surrounding landscapes at 500 and 1500 m radius. Coccinellid traits (activity peak, predominant dispersal mode, habitat generalization, rareness/commonness, body size, and ubiquity) were gathered from previous studies. R-mode linked to Q-mode (RLQ) analysis showed that coccinellid community break into three groups of trait syndromes in their response to landscape composition and heterogeneity at both spatial scales. Group A was composed by species with tendency to aerial dispersal, generalists, small and rare; Group B by abundant, generalist and medium size species, with some differences in composition and traits between scales; and Group C by large, ubiquous, aerial and abundant species at both scales, and specialists and early at 1500 m. Landscape variables (area of alfalfa, Shannon diversity, edge density) at 500 and 1500 m, and aphid density in alfalfa are differentially related to these three groups. These results suggest that functional traits influence coccinellids community composition in alfalfa and respond differentially to landscape at different spatial scales. FONDECYT 1180533, 1230073.

Session 16-P2 - Biodiversity-based pest management practices

Multivarieties and cover crops to increase sustainability of Mediterranean pear orchards

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Pears, with more than 100,000 ha, are one of the most important fruit crops in Europe. In spite of the disadvantages of chemical control, the regulation of pest populations in pear orchards is still based on the use of broad-spectrum insecticides, which generally results in pest outbreaks. Additionally, the current climate change scenario is expected to increase pest abundance and reduce biodiversity. In this context, the DREAM project in Spain is looking for farming alternatives to increase resilience by using varieties with different phenology, and by implementing cover crops to enhance natural enemy populations. A pear orchard was set up to assess the effect of crop diversity (mono- or multi-varietal) and cover crop (presence-absence) on pests and natural enemies. These two factors were assayed in a complete factorial randomized block design with three repeats. Pear trees and the cover were sampled for arthropods using conventional methods along spring. The preliminary results show significant differences in the abundance of pear psyllid and aphids on pear trees among some of the pear varieties. Psyllids density was similar in the plots with and without cover; in contrast, the abundance of aphids on pear trees was higher in the presence of cover. No significant differences in the abundance of natural enemies were observed between mono- and multi-varietal plots, but the abundance of predatory mirids was higher in the presence of cover crops. The preliminary results of this project show that both crop diversity and enhanced floral resources may have an impact on the population dynamics of pests and natural enemies in pear orchards.

Session 18-P1 - Classical biological control in sub-tropical Africa

Smallholder farmers' knowledge, attitudes and practices towards biological control of papaya mealybug in Kenya

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Farmer perceptions are highly important in influencing on-farm pest management decision-making. Biological control is extremely sustainable in the smallholder production context however, in Sub-Saharan Africa (SSA) few attempts using this pest control method for arthropod pests have been successful, with one of the key reasons cited as poor involvement of farming communities and extension in the dissemination of information. Papaya mealybug (*Paracoccus marginatus*) (PMB) has rapidly spread and established in suitable areas across Kenya becoming a serious pest. The objective of this study was to determine smallholder farmers' knowledge, attitudes and practices towards biological control; willingness to reduce chemical pesticide use; and levels of support for classical biological control for PMB management. Household surveys covered 383 farming households in four papaya producing counties in Kenya alongside focus group discussions and key informant interviews.

Although some farmers demonstrated awareness of the concept of biological control they lacked knowledge, experience and technical support from extension or agro-dealers. Reasons for not using biological control included inadequate awareness and concerns over efficacy and safety. Farmers expressed high levels of interest and willingness to support biological control and were willing to reduce their chemical pesticide use to help conserve and support establishment of natural enemies. County, perception of biological as safe, IPM training and gender were highly significant factors determining farmers willingness to support biological control. Previously, poor attention has been paid to farmer perceptions and participation in biological control, which has resulted in limited success in developing countries. By strengthening awareness and capacity and developing a management plan with farmers establishment of the biological control agent, *Acerophagus papayae*, for sustainable control of PMB, is possible.

Session 18-P2 - Classical biological control in sub-tropical Africa

Stability evaluation of formulations based on the entomopathogenic fungus *Beauveria bassiana*

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Agriculture plays a crucial role in Angola's development, being essential for food security and the economy. Growing awareness of reducing chemical pesticides is driving transformations, and Novagrolider leads On Farm bioinput production, focusing on biological solutions such as formulations with entomopathogenic fungi as a sustainable strategy to enhance agricultural productivity. Thus, the objective of this study was to evaluate the stability of seven formulations based on the fungus *Beauveria bassiana* ATCC 74040 strain. Fungal inoculum was established at 10^9 conidia and the commercial product Naturalis® was used as a positive control. *B. bassiana* (Bb), mineral oil (Mo), anionic surfactant (As), water (Wa), neem oil (No), orange oil (Oo), and buttermilk (Bu) were used in the following formulations: F1 (Bb/Mo and As(1.6%)); F2 (Bb/Mo:Wa emulsion (50:50) As (1,6%)); F3 (Bb/No and As (1.6%)); F4 (Bb/Bu:Wa (50:50)/ No (10%) emulsion and As (1.6%)); F5 (Bb/Oo/Mo/Wa (25/25/25) emulsion and As (1.6%)) e F6 (Bb/Oo and As (1.6%)). The kinetic stability, centrifugation stability, and pH of formulations were evaluated from 24 hours to the 10 days after production, under three temperatures: 8°C, 25°C and 35°C, in triplicates within a completely randomized design. Using the R software, to assess the impact of factors on the stability among the formulations, a two-way variance analysis (ANOVA) was conducted, along with the Tukey test, both at $p < 0.05$. Additionally, a principal component analysis (PCA) was performed to evaluate patterns among the formulations. The temperature of 25°C was related to the best stability for F1, F2, F3, F4 and F5 for kinetic stability and F1, F2 and F3 for centrifugation stability, in addition to pH variations for F4, F5 and F6, these results are related to flocculation and sedimentation processes, suggesting that such formulations are viable for use in the stock mix, and as possible formulations of *B. bassiana.*

Session 19-P1 - Biological control of plant diseases

Biocontrol sweet spot: stepwise screenings toward the identification of bacterial strains protecting strawberries from *Phytophthora cactorum* root and crown rot

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Phytophthora cactorum is a soilborne pathogen widespread in all continents, highly problematic in horticulture: (i) it is hard to contain, as motile zoospores swim far and fast, (ii) it is hard to eradicate, as dormant oospores survive in the soil and cause infection for years, and (iii) it has a very broad host spectrum and affect more than 200 plant species, among which many economically relevant crops. In strawberry cultivation in particular, *P. cactorum* decreases the yield by up to 30% both pre- and post-harvest: it causes root, crown, and leather rot, eventually stunting the whole plant. Management is challenging, as *P. cactorum* develops resistance to oomycides, and many chemicals are being phased out for their detrimental effects on human health and the environment. By bypassing these pitfalls, biological control is envisaged by policymakers and researchers as an ideal alternative, but few biocontrol-based alternatives are available on the market to date.

For this sake, we performed a comprehensive and stepwise screening to identify biocontrol organisms (BCOs) for the *P. cactorum* – strawberry pathosystem. A collection of 300 bacteria, mostly *Pseudomonas* and *Bacillus* spp., was screened for their antagonistic activity in an innovative high-throughput *in vitro* assay. By using spores as a pathogen inoculum instead of mycelium for confrontation assays, we were able to study both mycelium and spore inhibition at once. Candidates with strong *in vitro* activity were characterized for the production of lytic enzymes, bioactive supernatants and volatiles, as well as their activity against other phytopathogens. The antagonism of the top performers was assessed in planta, in detached leaf bioassays and greenhouse trials. We identified several candidate BCOs with antagonistic activity both in vitro and in planta. In an effort to decipher the underlying mode of action, we sequenced, assembled, and annotated their genomes to identify biosynthetic gene clusters.

Session 19-P3 - Biological control of plant diseases

Actinobacteria, natural enemies of the root-knot nematode *Meloidogyne javanica*

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Soil microbiota is an important source of biocontrol agents against phytopathogens. Among microorganisms, actinobacteria stand out, and species of the genus *Streptomyces* are the most studied in controlling the root-knot nematode *Meloidogyne javanica*, one of the most limiting nematodes worldwide. Currently, there is a need to explore other genera of bacteria with antagonist potential against the root-knot nematode. The objective of this research was to select bacteria isolated from soil in Villavicencio, Meta, Colombia, for the control of the root-knot nematode *M. javanica*. Bacteria were initially isolated using the dilution method, and then *in vitro* tests were applied to evaluate parasitism of *M. javanica* eggs. Finally, *in vivo* trials on tomato plants treated with actinobacteria and inoculated with *M. javanica* eggs confirmed their ability to control the root-knot nematode. A total of 5 filamentous bacteria, Act1, Act2, Act3, Act4, Act5, was evaluated. The results demonstrated the ability of all actinobacteria to parasitize eggs. In addition, plants treated with actinobacteria, 55 days after nematode inoculation, showed significant reductions in the number of *M. javanica* eggs per gram of root. The results confirm the importance of studying and selecting microorganisms with biocontrol potential against the root-knot nematode *M. javanica.*

Session 20-P1 - Role of microbials in sustainable agriculture

Potential of the extract obtained from *Aspergillus nomiae* for the biocontrol of *Spodoptera frugiperda*

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Currently, traditional methods of chemical pest control have been questioned, as they can have adverse effects on the environment and human health. Thus, the search for biological entomopathogenic alternatives becomes increasingly attractive, accelerating the search for efficient and safe biocontrollers. Therefore, we tested the hypothesis that an extract obtained from *Aspergillus nomiae* could affect the survival of *Spodoptera frugiperda* caterpillars, a pest known to impact grain crops around the world. A methanolic extract of the fungus was used in bioassays of indirect exposure of 1st instar larvae, through the diet, being supplied at a concentration of 100, 200 and 250 µL, dispersed over the caterpillars' diet. As a control, we used caterpillars exposed to 250 µL of methanol. At 28 days after exposure, we found mortality of 74, 94 and 98%, respectively, in caterpillars treated with 100, 200 and 250 µL of the fungal extract. On the other hand, in the control treatment, we observed an average mortality of only 36 %. In the caterpillars treated with 250 µL of the extract, the 2% of surviving caterpillars died in the L4 phase, while the survivors treated with 200 µL, 2% died in L2, 2% in L5, 2% in L6 and only 2% formed pupa, which died and did not generate postures. In the surviving caterpillars treated with 100 µL of the extract, 2% died in L2, 12% in L5 and 8% formed pupa, these pupae converted into adult insects, which generated 8 postures, but these did not hatch. On the other hand, in the surviving caterpillars from the control treatment, only 4% died in the L5 phase and 32% formed pupae. These pupae produced adults that had 39 postures, all of which were viable. Our results prove that the extract containing secondary metabolites of *A. nomiae* has potential for the biocontrol of *S. frugiperda*.

Session 20-P2 - Role of microbials in sustainable agriculture

Co-application of biochar and soil actinobacteria and its effect on the promotion of plant growth in tomato plants

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Soil microbiota contributes to soil health and play a crucial role in promoting plant growth. Among microorganisms, actinobacteria improve crop yields, and their co-application with biochar promotes proliferation and performance due to the nutrient source and favorable conditions for growth. The objective of this research was to evaluate the effect of the co-application of actinobacteria and biochar on the promotion of tomato plant growth. Three actinobacteria were isolated from soil samples using the serial dilution method. Additionally, biochar was obtained through pyrolysis using cocoa shells as a plant material. In the *in vivo* tests, Milano variety tomato plants were used. The experiment was conducted under greenhouse conditions in organic substrate. The treatments included: Actinobacteria1 (Act1), Actinobacteria2 (Act2), Actinobacteria3 (Act3), Biochar (B) 2% w/w, Act1+B, Act2+B, Act3+B, Commercial Treatment Rizofos® (*Pseudomonas fluorescens*) (C), C+B, and control (T). Each plant that received bacteria was inoculated with 2,2 x 10^7 spores at the time of transplant, the biochar was incorporated into the substrate before transplanting. At 49 days after transplanting, the results showed that the co-application of bacteria-biochar significantly increased the percentage of dry matter in the aboveground part, stem diameter, chlorophyll content, and number of flowers, demonstrating better results than independent applications of biochar or actinobacteria. These findings highlight the importance of incorporating biochar as a substrate amendment to promote the development and interaction between microorganisms and plants.

Session 20-P3 - Role of microbials in sustainable agriculture

Potential of beneficial microorganisms present in biodiverse compounds based on angiorperm and gymnosperm for foliar protection of *Glycine max*

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Biodiverse compounds (BC) are obtained from the litter of different plant species, being used in regenerative agriculture to recover the soil's food web, as they bring together groups of beneficial microorganisms that will exert functional traits that are important for crop growth and productivity. On the other hand, tea obtained from BC aims to provide foliar protection through the formation of biofilm, helping to control diseases. When applied by spraying, the fungi and bacteria multiplied during the preparation of compost tea cover the leaf cuticle and exert direct or indirect antibiosis against agricultural pests. Thus, we raised the hypothesis that tea extracted from different BCs, produced from Angiosperm or Gymnosperm, could control pests in *Glycine max* cultivation. For this, we installed soybean cultivation plots subjected to 05 treatments (control – CT; inoculation of *Azospirillum brasilense* + *Bradyrhizobium japonicum* (AB + BJ); inoculation of *A. brasilense* + *B. japonicum* + spraying of tea based on BC of gymnosperm (AB + BJ + G); inoculation of *A. brasilense* + *B. japonicum* + spraying of tea based on BC of angiosperm (AB + BJ + A); spraying of tea based on BC of gymnosperm (G); spraying of tea based on BC of angiosperm (A)). In these plots we check the number of leaves showing disease symptoms (attacked by fungi) and attacked by grazing insects. We found in CT plants the highest average number of leaves attacked by fungal diseases (12.1), while plants treated with G showed the lowest leaf incidence of fungal diseases (6.7). Similarly, CT plants presented an average of 28.5 leaves attacked by grazing insects, while plants from treatments AB + BJ, AB + BJ + G and AB + BJ + A showed similar average values (21.6, 21.3 and 21.7 respectively). Those treated with A and G had the lowest average incidences (9.5 and 8.7). Our results attest to the potential of BCs, especially those produced from gymnosperm, to protect *G. max* against pest attacks.

Session 20-P5 - Role of microbials in sustainable agriculture

Transcriptome dynamics underlying chlamydospore formation in *Trichoderma virens* GV29-8

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Trichoderma spp. are widely used biocontrol agents which are antagonistic to a variety of plant pathogens. Chlamydospores are a type of propagules produced by many fungi that have thick walls and are highly resistant to adverse environmental conditions. Chlamydospore preparations of *Trichoderma* spp. can withstand various storage conditions, have a longer shelf life than conidial preparations and have better application potential. However, large-scale production of chlamydospores has proven difficult. To understand the molecular mechanisms governing chlamydospore formation (CF) in *Trichoderma* fungi, we performed a comprehensive analysis of transcriptome dynamics during CF across 8 different developmental time points, which were divided into 4 stages according to PCA analysis: the mycelium growth stage (S1), early and middle stage of CF (S2), flourishing stage of CF (S3), and late stage of CF and mycelia initial autolysis (S4). 2864, 3206, and 3630 DEGs were screened from S2 vs S1, S3 vs S2, and S4 vs S3, respectively. We then identified the pathways and genes that play important roles in each stage of CF by GO, KEGG, STC and WGCNA analysis. The results showed that DEGs in the S2 vs S1 were mainly enriched in organonitrogen compound metabolism, those in S3 vs S2 were mainly involved in secondary metabolite, cell cycle, and N-glycan biosynthesis, and DEGs in S4 vs S3 were mainly involved in lipid, glycogen, and chitin metabolic processes. We speculated that mycelial assimilation and absorption of exogenous nitrogen in the early growth stage (S1), resulted in subsequent nitrogen deficiency (S2). At the same time, secondary metabolites and active oxygen free radicals released during mycelial growth produced an adverse growth environment. The resulting nitrogen-deficient and toxin enriched medium may stimulate cell differentiation by initiating cell cycle regulation to induce morphological transformation of mycelia into chlamydospores. High expression of genes relating to glycogen, lipid, mannan, and chitin synthetic metabolic pathways during the flourishing (S3) and late stages (S4) of CF may be conducive to energy storage and cell wall construction in chlamydospores. For further verifying the functions of the amino sugar and nucleotide sugar metabolism (tre00520) pathway in the CF of *T. virens* GV29-8 strain, the chitin synthase gene (TRIVIDRAFT_90152), one key gene of the pathway, was deleted and resulted in the dysplasia of mycelia and an incapability to form normal chlamydospores, which illustrated the pathway affecting the CF of *T. virens* GV29-8 strain. Our results provide a new perspective for understanding the genetics of biochemical pathways involved in CF of *Trichoderma* spp.

Session 23-P1 - Adoption of IPM for successful biological control

Biological control as part of the soybean Integrated Pest management (IPM): the success of a Brazilian programme

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Soybean is considered one of today's most important crops. Planted on millions of hectares worldwide, the management of soybean pests usually requires large amounts of chemicals. However, a key component to meet the increasing demand for food due to the rapidly growing global population is protecting crops from pests while maintaining environmental quality through ecologically and economically sound integrated pest management (IPM) practices. Currently, integrated pest management (IPM) is one way to protect crops through the integration of different pest control tools based on plant tolerance, adoption of economic thresholds (ETs), scouting procedures, use of selective insecticides, biological control, and other sustainable pest management tools, which helps to maintain environmental quality in an ecological and economical manner. Simple practices of IPM such as reducing insecticide use (with the adoption of economic thresholds), prioritizing harmless insecticides or biopesticides, and planting resistant soybean cultivars can preserve natural enemies that represent an important mortality factor that can keep the damage caused by pests below the economic threshold levels without additional control actions. These IPM practices favor the conservation and increase of the population of natural enemies in crops, as well as the massive release of Applied Biological Control (ABC) agents have been adopted in Brazil with positive results. The soybean-IPM case study in Brazil is an example of how it is possible to manage soybean fields sustainably, preserving or even increasing productivity and reducing production costs, consequently, maximizing profits, when IPM strategies are adopted.

Session 23-P2 - Adoption of IPM for successful biological control

IPM by essential oils: hard with aphids, soft with their predators

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Essential oils are naturally occurring highly complex mixtures of volatile and semi-volatile organic compounds produced by different plant families, that fit perfectly well into IPM programs provided that their effectiveness against the pest and safety against the beneficial fauna can be ensured. Aphids are very well known as a highly challenging pest, especially in Mediterranean greenhouses, due to their high reproduction rate, the development of resistance to insecticides, and their role as plant virus vector. Although fight against aphids is dominated by synthetic insecticides it is desirable to have natural alternatives that can fill the gap left by synthetic products that are being banned by national and supranational legislation. Essential oils are a very promising alternative to chemical insecticides. In a continuous search for the best conditions for essential oils to be applied with optimum results, we are exploring the possibility of enhancing the effectiveness of these natural insecticides by combining two different essential oils. Here we present preliminary results on the effectiveness of cypress (*Cupressus sempervirens* L.) and laurel (*Laurus nobilis* L.) essential oils in contact toxicity bioassays against the green aphid (*Myzus persicae* Sulzer) and one of their natural enemies, the syrphid (*Sphaerophoria rueppellii*). Air-dried plant material (samples of around 50 g) was hydrodistilled (1 g dw/10 mL distilled water) in a Clevenger-type apparatus for 3 h. Distilled oils were dried over anhydrous sodium carbonate and stored in amber airtight glass vials at 4°C until use. The composition of the essential oils was characterized by gas chromatography-mass spectrometry and identified by comparing mass spectra with those in NIST v11 library. Results shows promising synergistic effects when combining both essential oils with respect to essential oils alone and open up a promising avenue for the more efficient application of this type of compounds.

Session 23-P3 - Adoption of IPM for successful biological control

Adopting mixed cropping systems to foster biocontrol and manage oviposition of a mayor belowground insect pest

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Identification of attractive plant species enables management of oviposition sites, and strengthens the control of click beetles within mixed cropping systems. Wireworms, the larvae of click beetles (Coleoptera: Elateridae), are an important soil-dwelling insect pest, and to date no sufficient control measure is available. Intensive soil tillage in summer, and trap cropping combined with entomopathogenic fungi (EPF) application are to date the most promising biocontrol strategies to combat wireworms. While many control approaches focus on the larval stage, management of adults has mostly been limited to pheromone trapping. Managing the spatial oviposition choice of female click beetles could help to generate an efficient, long-term control system for wireworms. So far, it has not been investigated to what extent plant volatiles play a role in the females' selection of suitable oviposition sites. We performed electroantennography (EAG) and behavioral experiments in an optimized olfactometer to identify attractive plants and volatiles for click beetles of the species *Agriotes sputator*. Within these experiments, wheat, clover and ryegrass were identified to be the most attractive plants. Identification of highly attractive plant species provides the base for advanced crop rotations in mixed cropping systems. Within these cropping systems, attractive crops could be avoided before sensitive crops or used to concentrate and control eggs and emerging larvae in oviposition strips in field margins. When trap crops are combined with the application of EPFs for the control of larvae, trap crops strips could be used to attract adult beetles for oviposition. Subsequently emerging wireworms are infected by EPF spores, and wireworm populations reduced for future years. Beside biocontrol, this adapted mixed crop rotation provides valuable ecosystem services, since in-field biodiversity is boosted.

Session 23-P4 - Adoption of IPM for successful biological control

Evaluating sub-lethal behavioral effects of plant protection products on *Trissolcus* parasitoid

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The efficiency of parasitoids in finding their host is crucial for the effectiveness of biological control programs. Since parasitoids spend most of their adult life searching for their host, walking behavior, chemical, and visual stimuli, as well as their detection capacity, can be potentially altered by plant protection products used in IPM, such as insecticides, fungicides, and plant-strengtheners. *Trissolcus japonicus* Ashmead (Hymenoptera: Scelionidae) and *Trissolcus mitsukurii* Ashmead (Hymenoptera: Scelionidae) are two Asian egg parasitoids of the invasive Asian brown marmorated stink bug, *Halyomorpha halys* Stål (Hemiptera: Pentatomidae). The effect of repellence of pesticides could play a role in reducing parasitoid discovery efficiency in field conditions. The behavioral effect induced by exposure to dry residues of plant protection products has been tested in terms of repellence/deterrence to *T. japonicus* and *T. mitsukurii* using a laboratory video-tracking method. Results showed that some plant protection products had a sub-lethal deterrence effect toward *T. japonicus* and *T. mitsukurii*. The alteration of parasitoid behavior induced by plant protection practices can alter their efficacy even though treatments do not have a direct effect on their survival and reproduction.

Session 23-P5 - Adoption of IPM for successful biological control

Selectivity of hymenopterans in attractants and traps for monitoring fruit flies

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Pest monitoring is essential to integrated pest management in agricultural systems. The use of specific attractants and traps is common for quantifying pest population density in the field. However, it is crucial to assess the selectivity of these traps and attractants to avoid capturing non-target insects, particularly beneficial insects. Insects belonging to the order Hymenoptera play an important role in biological systems, both as pollinators and possible biological control agents. Avoiding their capture contributes to the preservation of field populations and the effectiveness of biological control strategies. This study evaluated the selectivity of attractants and traps for capturing fruit flies (Drosophilidae family) versus benign non-targets during the grape ripening period. The experiment was conducted in a vineyard in São Joaquim, Santa Catarina, Brazil, during the 2019/20 crop season. A randomized block experimental design was used in a 2 x 4 factorial scheme, with two trap types (PET bottle and plastic pot) and three attractants (Suzuki Trap®, Droskidrink, and yeast), and distilled water as a control. The traps were deployed three times during grape maturation, each remaining in the field for one week. While there was no significant difference in the number of captured hymenopterans between PET Bottle and Plastic Pot, an effect of the attractant was found. Suzuki Trap® (1.85 ± 0.90) and Droskidrink (2.12 ± 0.45) attractants resulted in lower capture rates for hymenopterans, while yeast (5.58 ± 2.56) provided the highest capture rate. The combination of plastic pot and Droskidrink proved to have the lowest non-target effects and selective against hymenopteran capture (1.50 ± 0.50) while also having highest fruit fly capture rate (9.33 ± 1.97). Our findings emphasize the need for careful consideration of trap types and attractants to avoid capturing non-target insects.

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