



International Organisation for Biological and Integrated
Control of Noxious Animals and Plants (IOBC)
West Palearctic Regional Section (WPRS)



**The 9th meeting of the
IOBC/WPRS Working Group**

**Integrated Control in Protected Crops,
Mediterranean Climate**

Working Group Meeting

Pest Management in an Ever-Changing World

11-15 October 2015

**The
Robert H. Smith Faculty of Agriculture, Food & Environment
The Hebrew University of Jerusalem**

Rehovot, ISRAEL



WELCOME

We are happy to welcome you to the 9th meeting of the Working Group on the campus of the R.H. Smith Faculty of Agriculture, Food and Environment of the Hebrew University of Jerusalem in Rehovot, Israel.

The theme we chose for the meeting, **Pest Management in an Ever-Changing World**, reflects the constant changes in climate, consumer demand, economy, regulations, technology, as well as invasions of new pest species, that continuously challenge researchers, extension officers, growers and the agro-businesses. These changes are evidenced throughout the meeting program.

The four days of the meeting will include keynote talks by leading scientists, oral research reports, three guest speakers that will explore new approaches and ideas, discussion sessions, and a full day field trip to a major greenhouse production region in the Arava valley. We also allowed ample of time for informal interaction during breaks, field trip, and evening events.

Now it is really over to you, the participant. How you benefit from the meeting will depend not only on your listening to the talks but also on your active participation; we encourage you to ask questions and actively participate in discussions. We trust you will take the opportunity to approach people you haven't met before and then network further over dinner, wine, and coffee, or on the bus on Tuesday.

We worked hard to create the best possible scientific, professional and personal experience for you. Please feel free to approach any of us for assistance or with suggestions. We will do our best to help.

Finally, we wish to thank the IOBC-WPRS and the Hebrew University of Jerusalem (The Authority for Research & Development, the Faculty of Agriculture, Food & Environment, and the International School of Agricultural Sciences) for their financial and logistic support, and the generous sponsorship by Koppert, BioBee, Stockton, and Bioplanet.

With our best wishes for a fruitful meeting and an enjoyable visit,

The Organizing Committee



Moshe Coll



Dan Gerling



Shimon Steinberg



Carmelo Rapisarda
WG Convenor



Mala Braslavsky
Secretariat

KEYNOTE SPEAKERS

Dr. Cristina Castañé Fernández (IRTA, Cabrils, Barcelona, Spain)



Dr. Castañé is an entomologist at IRTA (Research Institute for Agriculture of the Catalan government, Spain) with experience in research, development and transfer of integrated pest management (IPM) programs for horticultural crops and stored products. Her main expertise is in biology and ecology of pests and natural enemies for the development of biological control programs in vegetable crops and stored products. From 2003-2012, she has been the convener of the IOBC/WPRS Working Group on “Integrated Control in Protected Crops, Mediterranean Climate”

Dr. Gerben J. Messelink (Wageningen University, The Netherlands)



Dr. Messelink works at Wageningen UR Greenhouse Horticulture as an applied entomologist on biological control of arthropod pests in greenhouse crops. His main focus is on generalist predatory mites for the control of thrips, whiteflies, spider mites and Tarsonemid and Eriophyid mites in several greenhouse cropping systems. He is also very interested in interactions within food webs of several pests and natural enemies, which was also the topic of his PhD thesis (was completed in collaboration with the University of Amsterdam). His present works on generalist predators includes anthocorid and mirid predatory bugs. Currently, he is involved in several research projects that deal with the evaluation of new natural enemies and developing systems that enhance establishment and persistence of natural enemies for control of thrips, spider mites, whiteflies, aphids and mealybugs.

Prof. Michael P. Parrella (University of California at Davis, USA)



Dr. Parrella's research is focused on developing integrated pest management programs for greenhouse and nursery crops with an emphasis on biological control. His research has recently focused on how soil amendments and the microbiome in the rhizosphere affect overall plant health, pests and natural enemies.

Dr. Parrella is a Professor and Chair at the Department of Entomology and Nematology, University of California, Davis.

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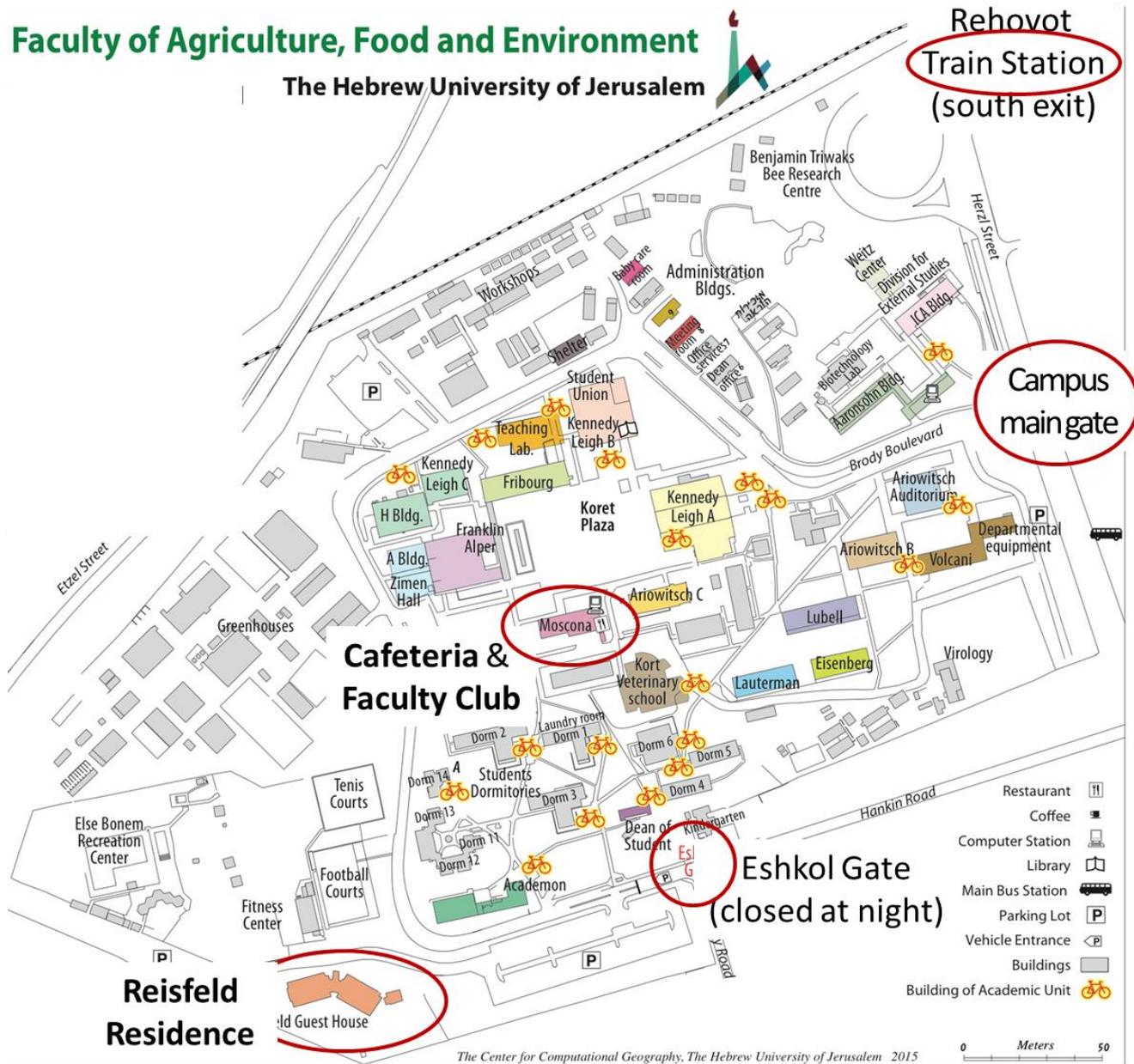
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CAMPUS MAP

(Showing locations of main functions)

Faculty of Agriculture, Food and Environment

The Hebrew University of Jerusalem



THE PROGRAM AT A GLANCE

Sunday	Monday	Tuesday	Wednesday	Thursday
	09:00 - 09:30 Welcome and greetings – <i>M. Coll</i>		Session II: Integrated Pest Management Moderator: <i>C. Rapisarda</i>	09:00-10:00 WG business meeting – <i>C. Rapisarda</i>
	Session I: Biological Control Application Moderator: <i>E. Palevsky</i>		09:00-09:10 Introduction – <i>C. Rapisarda</i>	Session III: Biology of BioControl Agents Moderator: <i>D. Gerling</i>
	09:30-09:40 Introduction - <i>E. Palevsky</i>		09:10-09:55 Keynote Talk – <i>M.P. Parrella</i>	10:00-10:10 Introduction - <i>D. Gerling</i>
	09:40-10:25 Keynote Talk – <i>G.J. Messelink et al.</i>		09:55-10:15 II-1 – <i>D.S. Kittich, M.P. Parrella</i>	10:10-10:55 Keynote Talk – <i>C. Castañe</i>
	10:25-10:45 I-1 – <i>E. Figueiredo, J. Martins, R. Nunes et al.</i>		10:15-10:35 II-2 – <i>A. Bassi et al.</i>	10:55-11:15 III-1 – <i>N-W. Yang, D. Gerling, F-H. Wan</i>
	10:45-11:15 Coffee break	07:00- 18:30	10:35-11:00 Coffee break	11:15-11:35 Coffee break
	11:15-11:35 I-2 – <i>K. Karut, C. Kazak, I. Döker</i>		11:00-11:20 II-3 – <i>R.A. Horowitz et al.</i>	11:35-11:55 III-2 – <i>S. Eshet et al.</i>
	11:35-11:55 I-3 – <i>F. Calvo et al.</i>	Field trip to the Arava Valley	11:20-11:40 II-4 – <i>G. Tropea Garzia et al.</i>	11:55-12:15 III-3 – <i>G.J. Messelink et al.</i>
	11:55-12:15 I-4 – <i>A. Sade et al.</i>		11:40-12:00 II-5 – <i>L. Shaltiel-Harpaz et al. & E. Palevsky</i>	12:15-12:35 III-4 – <i>M. Salomon-Botner, M. Coll</i>
	12:15-12:35 I-5 – <i>E. Figueiredo, J. Martins, T.Matos et al.</i>		12:00-12:20 II-6 – <i>P. Ferreira et al. & A. Aguiar</i>	12:35-12:55 III-5 – <i>T. Schuldiner-Harpaz, M. Coll</i>
	12:35-12:55 I-6 – <i>T. Groot</i>		12:20-13:50 Lunch	12:55-13:40 Discussion – <i>D. Gerling</i>
	12:55-14:15 Lunch		13:50-14:10 II-7 – <i>J.A. Otiemo, H.-M. Poehling</i>	13:40-14:00 Meeting Wrap-up – <i>S. Steinberg</i>
	14:15-15:15 Invited Talk – <i>E. Moerman</i>		14:10-14:30 II-8 – <i>M. Naselli et al. & G. Siscaro</i>	14:00 Lunch
	15:15-15:55 Invited Talk – <i>S. Steinberg</i>		14:30-14:50 II-9 – <i>L. Shaltiel-Harpaz et al.</i>	
	15:55-16:15 Coffee break		14:50-15:30 Invited Talk – <i>Y. Elkind</i>	
			15:30-15:50 Coffee break	
19:00 Registration	16:15-17:00 Discussion – <i>E. Palevsky</i>	<i>Israeli dinner (own)</i>	15:50-16:35 Discussion – <i>C. Rapisarda</i>	
19:00 Mix & mingle reception	17:00-22:00 Evening in Jaffa + <i>(own) Dinner</i>		18:30 Gala dinner	

THE PROGRAM

Sunday
11 October 2015
Reisfeld Residence

16:00 – 19:00	Registration
19:00	Mix & Mingle Reception

Monday
12 October 2015
Faculty Club

09:00 – 09:30	Welcome and greetings – <i>Prof. M. COLL</i> , Organizing committee <i>Prof. B. CHEFETZ</i> , Acting Dean <i>Prof. C. RAPISARDA</i> , WG Convener
Session I: Biological Control Application Moderator: <i>Eric PALEVSKY</i>	
09:30 – 09:40	Introduction – <i>Eric PALEVSKY</i>
09:40 – 10:25	Keynote Talk – Developments in the “standing army approach” for biological pest control in protected crops <i>Gerben MESSELINK</i> ; <i>Chantal BLOEMHARD</i> ; <i>Renata VAN HOLSTEIN-SAJ</i> ; <i>Ada LEMAN</i>
10:25 – 10:45	Talk I-1 – The tiger-fly <i>Coenosia attenuata</i> as a biological control agent in protected crops in the Oeste region, Portugal <i>Elisabete FIGUEIREDO</i> ; <i>Joana MARTINS</i> ; <i>Raquel NUNES</i> ; <i>André GARCIA</i> ; <i>Célia MATEUS</i>
10:45 – 11:15	Coffee break
11:15 – 11:35	Talk I-2 – Single and Combined Releases of <i>Eretmocerus mundus</i> and <i>Macrolophus melanotoma</i> against <i>Bemisia tabaci</i> in protected-eggplant <i>Kamil KARUT</i> ; <i>Cengiz KAZAK</i> ; <i>Ismail DÖKER</i>
11:35 – 11:55	Talk I-3 – Evaluation of <i>Amblydromalus limonicus</i> (Garman and McGregor) (Acari: Phytoseiidae) for whitefly and thrips control in protected crops <i>Francisco J. CALVO</i> ; <i>Jesús MORENO</i> ; <i>José E BELDA</i>
11:55 – 12:15	Talk I-4 – Biological control of the red spider mite in tomatoes under arid and semi-arid conditions in Israel. <i>Amit SADE</i> ; <i>Arnon TABIC</i> ; <i>Arnon ALLOUCHE</i> ; <i>Avi PREISLER</i> ; <i>Shimon STEINBERG</i>

12:15 – 12:35	Talk I-5 – Mirid complex in Oeste region greenhouse – <i>Dicyphus umbertae</i> a promising biological control agent? <u><i>Elisabete FIGUEIREDO</i></u> ; <i>Joana MARTINS</i> ; <i>Tiago MATOS</i> ; <i>Gonçalo DUARTE</i> ; <i>Elsa BORGES SILVA</i> ; <i>António MEXIA</i>
12:35 – 12:55	Talk I-6 – New possibilities with old natural enemies <u><i>Tom GROOT</i></u>
12:55 – 14:15	Lunch
14:15 – 15:15	<u>Invited Talk</u> – How biostimulants help to grow more with less <u><i>Ed MOERMAN</i></u>
15:15 – 15:55	<u>Invited Talk</u> – Prospects & challenges in practicing biologically-based IPM under arid & semi-arid conditions: A biocontrol producer's perspective <u><i>Shimon STEINBERG</i></u>
15:55 – 16:15	Coffee break
16:15 – 17:00	Discussion – <i>Eric PALEVSKY</i>
17:00 – 22:00	Evening in Jaffa + (own) Dinner

Tuesday 13 October 2015

07:00 – 18:30	Field trip to a greenhouse production area in the Arava valley – <i>leaving from Reisfeld Residence parking lot</i>
18:30	Israeli dinner (own)

Wednesday 14 October 2015 *Faculty Club*

Session II: Integrated Pest Management Moderator: <i>Carmelo RAPISARDA</i>	
09:00 – 09:10	Introduction – <i>Carmelo RAPISARDA</i>
09:10 – 09:55	<u>Keynote Talk</u> – Managing Invasive Species in the Greenhouse and Nursery: A Comprehensive Systems Approach <u><i>Michael P. PARRELLA</i></u>
09:55 – 10:15	Talk II-1 – LED lighting and its effects on <i>Liriomyza trifolii</i> (Diptera: Agromyzidae) oviposition compared to traditional lighting sources <u><i>Daniel S. KLITTICH</i></u> ; <i>Michael P. PARRELLA</i>

10:15 – 10:35	<p>Talk II-2 – The alternation of insecticidal modes of action as a key IPM practice for sustainable control of <i>Tuta absoluta</i> (Meyrick) <u>Andrea BASSI</u>; Emmanouil RODITAKIS; Jean Luc RISON</p>
10:35 – 11:00	<i>Coffee break</i>
11:00 – 11:20	<p>Talk II-3 – Effect of the organic insecticide, DeccoTab[®] on the whitefly <i>Bemisia tabaci</i> <u>Rami A. HOROWITZ</u>; Carolina GUZMAN; Galina LEBEDEV; Michael LAVI; Ofir DARDARY; Murad GHANIM</p>
11:20 – 11:40	<p>Talk II-4 – Efficacy of pyrethroid-impregnated nets in reducing impact of pests on vegetable crops <u>Giovanna TROPEA GARZIA</u>; Thibaud MARTIN; Antonio BIONDI; Lucia ZAPPALÀ; Nicolas DESNEUX; Carmelo RAPISARDA; Gaetano SISCARO</p>
11:40 – 12:00	<p>Talk II-5 – Developing environmentally safe control methods for <i>Fusarium oxysporum</i> for the prevention of bulb mite damage in onion Liora SHALTIEL-HARPAZ; Rieke KEDOSHIM; Tamar ALON; Yiftach GILADI; Leah TSROR; Segula MASAPHY; Shira GAL; Michael RAVIV; <u>Eric PALEVSKY</u></p>
12:00 – 12:20	<p>Talk II-6 – User-friendly methodology for risk assessment of <i>Tetranychus urticae</i> in hydroponic greenhouse production roses Pedro FERREIRA; Susana MACHADO; Susana CARVALHO; <u>Ana AGUIAR</u></p>
12:20 – 13:50	<i>Lunch</i>
13:50 – 14:10	<p>Talk II-7 – Additive and synergistic interaction amongst <i>Orius laevigatus</i>, Entomopathogens and Neem for Western Flower Thrips control <u>J.A. OTIENO</u>; H.-M POEHLING</p>
14:10 – 14:30	<p>Talk II-8 – Attractiveness and suitability of alternative plants for the omnivorous mirid <i>Nesidiocoris tenuis</i> Mario NASELLI; Antonio BIONDI; Emanuele DI BELLA; Michele RICUPERO; Giovanna TROPEA GARZIA; Carmelo RAPISARDA; Lucia ZAPPALÀ; <u>Gaetano SISCARO</u></p>
14:30 – 14:50	<p>Talk II-9 – Effect of wild and commercial tomato plants on <i>Tuta absoluta</i> and its omnivorous predator <i>Nesidiocoris tenuis</i> <u>Liora SHALTIEL-HARPAZ</u>; Tamir ROZENBERG; Moshe COLL</p>
14:50 – 15:30	<p><u>Invited Talk</u> – Vegetable breeding for Mediterranean greenhouse systems <u>Yonny ELKIND</u></p>
15:30 – 16:00	<i>Coffee break</i>

16:00 – 17:00	Discussion – Carmelo RAPISARDA
18:30	Gala dinner

Thursday
15 October 2015
Faculty Club

09:00 – 10:00	WG business meeting – C. Rapisarda
Session III: Biology of BioControl Agents Moderator: <i>Dan GERLING</i>	
10:00 – 10:10	Introduction – Dan GERLING
10:10 – 10:55	Keynote Talk – The use of mirids and anthocorid bugs as polyphagous predators in greenhouse crops <i>Cristina CASTAÑÉ; Nuria AGUSTÍ; Oscar ALOMAR</i>
10:55 – 11:15	Talk III-1– High temperature performance of <i>B. tabaci</i> parasitoids <i>Nian-Wan YANG; Dan GERLING; Fang-Hao WAN</i>
11:15 – 11:35	Coffee break
11:35 – 11:55	Talk III-2 – Bacterial symbionts of the omnivorous bug <i>Nesidiocoris tenuis</i> (Heteroptera: Miridae): biological control implications <i>Shaked ESHET; Einat ZCHORI-FEIN; Moshe COLL</i>
11:55 – 12:15	Talk III-3 – Endophyte induced plant responses enhance whitefly control in tomato by <i>Macrolophus pygmaeus</i> <i>Gerben J. Messelink; Renata VAN HOLSTEIN-SAJ; Henriëtte MARJOLEIN KRUIDHOF; Alexander SCHOUTEN; Julia HEBBINGHAUS</i>
12:15 – 12:35	Talk III-4 – On the interplay between omnivores' behavior and the nutritional value of plant and prey foods <i>Mor SALOMON; Moshe COLL</i>
12:35 – 12:55	Talk III-5 – The consumption of prey and plant foods by omnivorous coccinellid beetles: performance and feeding choice <i>Tarryn SCHULDINER-HARPAZ; Moshe COLL</i>
12:55 – 13:25	Discussion – Dan GERLING
13:25 – 14:00	Meeting Wrap-up – Shimon STEINBERG
14:00	Lunch

ABSTRACTS

(Arranged in alphabetic order by last name of first author;
Names of speaking authors are underlined)

The alternation of insecticidal modes of action as a key IPM practice for sustainable control of *Tuta absoluta* (Meyrick)

Bassi, Andrea¹; Emmanouil Roditakis²; Jean Luc Rison³

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² Institute of Olive Tree, Subtropical Crops and Viticulture, Hellenic Agricultural Organization –NAGREF, Heraklion, Greece;

³ DuPont de Nemours France, Centre Europeen de Recherche et Développement - 68740 Nambenheim, France.

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Abstract: despite the availability of innovative chemistry, the scientific community and IRAC have always warned that *Tuta absoluta* can only be sustainably controlled within consistent IPM strategies, integrating the available cultural, chemical, biological and biorational control practices. In this respect a key role is played by the alternation of the insecticidal MoA applied for *T. absoluta* control to avoid the build-up of resistance genes. This paper reports the sensitivity monitoring executed by DuPont and collaborators in Italy, Spain, Greece since 2009 in order to detect possible sensitivity shifts of *T. absoluta* from baseline sensitivity to the diamide insecticide chlorantraniliprole¹ (MoA group 28). The results of the 2014 bioassays revealed the first cases of *T. absoluta* resistance to diamide insecticides in South-East Sicily. The resistant strains feature high resistance ratios vs. sensitive strains. Unpublished molecular and inheritance studies indicate target-site mutations as the likely resistance mechanism involved. On-farm interviews have highlighted consistent abuse of chlorantraniliprole-based products over the last 5-6 years. Ways to cope are discussed, in view to possibly break the selection of resistance alleles via the adoption of stringent IPM strategies inclusive of reasoned IRM/MoA alternation programmes.

¹ MoA group 28 = ryanodine receptor modulator

Evaluation of *Amblydromalus limonicus* (Garman and McGregor) (Acari: Phytoseiidae) for whitefly and thrips control in protected crops

Calvo, J. Francisco; Jesús Moreno; José E Belda

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Abstract: Adoption of biological control-based integrated pest management programmes in protected crops has greatly increased in recent years in the Mediterranean area. Such phenomena has been in part as a result of the development of reliable and complete programmes which provide effective control of major pests such as the sweetpotato whitefly, *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) and the Western flower thrips, *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae). Biological control of these pests in cucumber is attained through augmentative releases of the phytoseiid predator *Amblyseius swirskii* Athias-Henriot (Acari: Phytoseiidae) and in sweet pepper with augmentative releases of *A. swirskii* and the anthocorid *Orius laevigatus* Fieber (Heteroptera: Anthocoridae). Although these strategies result effective under most situations, reproductive and growth rates of *A. swirskii* decline when temperatures decrease, especially under 15-18 °C, and thus the predator has more difficulties to keep pests under control in winter and particularly in non-heated greenhouses. Implementation of another control agent better adapted to such conditions would presumably increase effectiveness and consequently reliability of biological control programmes under winter conditions. The phytoseiid *Amblydromalus limonicus* (Garman and McGregor) (Acari: Phytoseiidae), which originates from more temperate regions than the Mediterranean species *A. swirskii*, remains active at lower temperatures than the latter, and could likely have the above-mentioned effects on biocontrol programmes. We therefore carried out several experiments to evaluate whether or not the use of *A. limonicus* would increase effectiveness of existing programmes for cucumber and sweet pepper based on the use of *A. swirskii* under winter and spring-summer conditions. Results showed that *A. limonicus* resulted more effective than *A. swirskii* against thrips in cucumber under winter conditions, but both predators resulted equally effective under the rest of climatic and crop conditions tested in our experiments.

Keynote Talk

The use of mirids and anthocorid bugs as polyphagous predators in greenhouse crops

Castañé, Cristina; Nuria Agustí; Oscar Alomar

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Abstract: Polyphagous predators have shown to be a viable solution for IPM programs in vegetable crops. In this paper advantages and disadvantages of using polyphagous predators are discussed. We also summarize existing experiences on the use of refuge plants to implement conservation programs. Recent experiences conducted by our group for the conservation of mirid and anthocorid bugs in tomato and lettuce Mediterranean crops are explained. The presence of refuge plants in the crop margins can increase the abundance of those polyphagous predators, advance their presence in the crop and facilitate their establishment, contributing to control crop pests, besides to be also beneficial to other neighbouring vegetable crops.

Bacterial symbionts of the omnivorous bug *Nesidiocoris tenuis* (Heteroptera: Miridae): biological control implications

Eshet, Shaked¹; Einat Zchori-Fein²; Moshe Coll¹

¹ Department of Entomology, RH Smith Faculty of Agriculture, Food & Environment, Hebrew University of Jerusalem, Rehovot, Israel

² Department of Entomology, Agricultural Research Organization, Neve Yaar Research Center, Ramat Yishay, Israel

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Abstract: Symbiotic microorganisms affect the performance of their insect hosts in many ways, including altering their reproduction, longevity, adaption to environmental changes, and nutritional needs. The present study was focused on the involvement of intracellular symbionts of gut tissues in the feeding behavior of the omnivorous bug *Nesidiocoris tenuis*.

N. tenuis occurs naturally in tomato fields in South Europe and the Middle East, where it preys upon major pest, such as the tomato moth, *Tuta absoluta*, spider mites, and whitefly nymphs. In addition, the bugs derive water and nutrients from tomato plants. Yet, unlike some other omnivorous insects, *N. tenuis* is an obligatory omnivore; it requires both prey and plant materials to complete its life cycle.

The large scale commercial use of *N. tenuis* against *T. absoluta* in tomato is hindered by damage it may inflict under some conditions; *N. tenuis* may cause necrotic rings on the stems, which might cause partial wilt. The objectives of this study were therefore to (i) Identify some of the major symbionts of *N. tenuis*, (ii) investigate how environmental factors affect gut symbiont composition, and (iii) unravel the effect of these symbionts on the ability of *N. tenuis* bugs to feed on prey and plant-based foods.

Two genera of secondary symbionts, *Wolbachia spp.* and *Rickettsia spp.*, were found to inhabit different cells of the bugs' gut. A large survey was conducted to detect environmental and agricultural correlates of symbiont occurrence. Results reveal a large variation in symbiont composition among host populations. Yet symbiont prevalence do not seem to vary with spatial association, pest control practice, tomato genotype and cropping system (protected vs. open field). In contrast, land surface temperature appears to greatly influence the abundance of these symbionts.

On-going experiments on *N. tenuis* with different symbiont compositions include quantification of the bug's feeding behavior on tomato plants, and its preference for and performance on prey vs. plant. Understanding how environmental factors influence symbiotic gut composition and the involvement of such symbionts in dietary choice by omnivorous natural enemies would suggest ways to increase prey intake and reduce plant damage through symbiont manipulations.

User-friendly methodology for risk assessment of *Tetranychus urticae* in hydroponic greenhouse production roses

Ferreira, Pedro¹; Susana Machado¹; Susana Carvalho^{1,2}; Ana Aguiar^{1,3}

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²*CBQ, Centro de Biologia e Química Fina, Universidade Católica, Porto, Portuga*

³*REQUIMTE, Laboratory for Green Chemistry, Porto, Prtugal*

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Abstract: Risk assessment will benefit the overall outcome of the whole crop production. For both the producer and anyone needing this data, it is absolutely relevant to have a quick and user-friendly way to obtaining it. During a comparison of different control methods of *Tetranychus urticae* on greenhouse roses, a lack of quick and user-friendly risk assessment methods was found and the need to have a way to quickly measure the intensity of the pest to keep up with its quick life-cycle became apparent.

As such, and in order to simplify the data assessment and improve decision making, a small comparative study was conducted in order to achieve a protocol for in-locus evaluation of this pest's intensity.

A four level scale based on mite counting has been proposed and an easy to use protocol for overall evaluation was presented. By obtaining an overall level for the entire area under study, a decision for treatment could be hastened and conducted without need for laboratory trials and destructive methods.

Mirid complex in Oeste region greenhouse – *Dicyphus umbertae* a promising biological control agent?

Figueiredo, Elisabete; Joana Martins; Tiago Matos; Gonçalo Duarte; Elsa Borges Silva; António Mexia.

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Abstract: Mirids are important predators for biological control of whiteflies and more recently, *Tuta absoluta* in tomato protected crop. However, since they are zoophytophagous they can also damage the plants. In 2006, a new species of *Dicyphus*, *D. umbertae*, was described by Sánchez, Martínez-Cascales and Cassis with specimens collected on open field tomato and on *Hyosciamus albus* in the Central-East and in the Southwest of Portugal. The complex of the mirid species present in protected crops in the Oeste region has been intermittently studied since 1995, before the releases of *Nesidiocoris tenuis* become a common practice. In 2011 and 2012, a new prospection was made and it was realized that the *Dicyphus* species referred as *D. cerastii* was in fact *D. umbertae*. Evolution on complex species composition along this time period and along the season is presented. Assays on predation and phytophagy behaviour of *D. umbertae* were made. This species is able to feed on whiteflies and *T. absoluta*. Vertical distribution on the plants was evaluated for *N. tenuis* and *D. umbertae*. In the laboratory, phytophagy in absence and in presence of prey were also evaluated.

The tiger-fly *Coenosia attenuata* as a biological control agent in protected crops in the Oeste region, Portugal

Figueiredo, Elisabete¹; Joana Martins¹; Raquel Nunes¹; André Garcia¹; Célia Mateus²

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Abstract: The tiger-fly, *Coenosia attenuata* Stein, was discovered in greenhouses of the Oeste region (Portugal) at the end of 2000. It is a predator both in larval and adult stages. In this ecosystem it is an important predator of whitefly adults. Assays in the laboratory and the field were carried out to study its impact as a biocontrol agent. The adults preyed all the potential prey tested (species of different taxa - Hemiptera: Miridae, Anthocoridae, Aphididae, Psyllidae Aleyrodidae, Pseudococcidae; Lepidoptera: Gelechiidae; Diptera: Psychodidae, Sciaridae, Cecidomyiidae, Agromyzidae Drosophilidae, Tephritidae; Hymenoptera: Braconidae, Eulophidae, Aphelinidae, Trichogrammatidae), except for *Trichogramma evanescens*, probably because it is too small, and also the majority of *Tuta absoluta* provided and *Ceratitis capitata*, probably because it is too big for them to attack. In choice arenas, this predator showed preference for pest species, especially whiteflies and leafminers, in relation to the parasitoid and predator species tested. The predation rate observed was 5.7 drosophilids/day or 10.7 whiteflies/day, higher than reported in literature. They preyed mainly on insects in flight, but could also attack immature insects when they moved rapidly. The number of predation holes and the time spent on feeding varied with the prey species and tended to be higher when feeding on bigger insects. In the laboratory cage studies, cannibalism by adults was lower when prey were present; cannibalism by larvae was not observed. Prey's colour did not affect predation rates. In the lab, in choice arenas the tiger-fly was more attracted to white than to yellow, green, blue and red sticky surfaces. The presence of earthworms and sciarid larvae increased oviposition but the tiger-fly larvae seemed not to be able to feed on intact earthworms but only on wounded or sliced ones.

New possibilities with old natural enemies

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Abstract: To the participants of this conference the need for more sustainable crop protection methods will be evident. This can only be achieved by an increased application of natural enemies in agriculture. Many authors have argued that we therefore need more species of natural enemies. These authors have pointed at the massive diversity of species that still has to be tested for their potential as natural enemy. However, to develop a new natural enemy becomes increasingly difficult. Adaptation of the Nagoya protocol and the Access and Benefit Sharing (ABS) results in researches having to negotiate with country governments before new species can be collected. This requires an investment in both time and money even before the potential of a species can be investigated. In addition, there is an increased awareness of the potential harm introduced natural enemies may do to indigenous non-target species. This has resulted in stringent demands in the registration process for new natural enemies. Not forgoing the potential of new species, I will argue that there are also new possibilities with the existing natural enemies. For example, using new introduction systems may allow for new uses. The development of rearing sachets with an extended release period for predatory mites has clearly taken the use of these mites to a higher level. Another example are breakthrough innovations in rearing techniques that may significantly reduce the price and availability of natural enemies. A recent development in the rearing of *Cryptolaemus montrouzieri* has allowed for the availability of a large scale larval product at a competitive price. Finally, exciting new possibilities will open up in the future when we start to select and breed for natural enemies with specific desirable traits. The EU funded BINGO ITN program contains several projects that are clear examples of what may be.

Effect of the organic insecticide, DeccoTab[®] on the whitefly *Bemisia tabaci*

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Abstract: The whitefly *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) is a pest of many agricultural systems and is classified within the top 100 world invasive species. This cosmopolitan insect gained its importance as one of the most destructive agricultural pests worldwide owing to its ability to feed on hundreds of plant species, many of which are important agricultural crops.

At present, the use of insecticides is the main approach employed to manage *B. tabaci* populations. However, there is a shortage in environmentally friendly pesticides to control the whitefly.

A novel formulation of an organic insecticide (DeccoTab[®]) was evaluated against *B. tabaci* (B and Q biotypes= MEAM1 and MED species, respectively) populations under controlled room and greenhouse conditions. The insecticide is formulated as microencapsulated essential oils, containing azadirachtin, citronella and natural pyrethrum.

Our experiments have shown that the use of DeccoTab at a concentration of 1% effectively controlled the adults and immature stages of MEAM1, but it affected adults of MED species to a lesser extent. Under controlled room conditions, it had a residual activity of approximately one week. In additional assays, the side effect of 1% DeccoTab on the predatory mite, *Amblyseius swirskii* (*Phytoseiidae*), was found to be minimal. We concluded that this compound is suitable to be used against adults and immature stages of *B. tabaci* for managing the pest in IPM programs and in organic farms.

Single and Combined Releases of *Eretmocerus mundus* and *Macrolophus melanotoma* against *Bemisia tabaci* in protected-eggplant¹

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Abstract: The parasitoid *Eretmocerus mundus* Mercet (Hymenoptera: Aphelinidae) and the predator *Macrolophus melanotoma* (Costa) (Hemiptera: Miridae) are recognized as two important natural enemies of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) that are distributed in all parts of the Mediterranean region. Previous studies indicated that a combined release strategy of *E. mundus* with *M. melanotoma* could be more successful than separate use of these two natural enemies in suppression of *B. tabaci* populations. In this study, we compared single and combined release of *E. mundus* and *M. melanotoma* against *B. tabaci* on eggplant in 3X3X3m net cages established in a greenhouse during the period of 2009 and 2010. Leaf samples were taken in order to determine population development of whitefly and the parasitoid at five-day intervals. In addition, numbers of the predatory insects on whole plants were counted using a naked eye method in different treatments. Results of this study showed that the numbers of whitefly was the highest in the control treatment followed by the *M. melanotoma* (alone), *E. mundus* (alone) and *E. mundus* + *M. melanotoma* (combined) treatments, in both years. According to this study, *M. melanotoma* was not successful to keep the whitefly population at low levels when released alone. However, it contributed to successful biological control when combined with the parasitoid *E. mundus*. Therefore, we suggest, combined release of *E. mundus* and *M. melanotoma* in order to obtain efficient whitefly control in protected eggplants.

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LED lighting and its effects on *Liriomyza trifolii* (Diptera: Agromyzidae) oviposition compared to traditional lighting sources

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Abstract: Supplemental lighting is an integral part of greenhouse production that has been shown to increase plant health and yield in many crops. The principal light source on the market to this point has been high pressure sodium lamps (HPS). However with the development, refinement, and reduction in cost of light-emitting diode (LED) technology, LED lighting systems are making their way into the supplemental lighting market. LED lights provide a smaller infrastructure footprint (shadowing), are lighter weight, and reduce energy usage per lighting output when compared to HPS systems. They are however at this point cost prohibitive (although this is changing rapidly) and there are concerns about longevity and maintenance. LED systems differ in one other major aspect from HPS systems in that each LED emits a very specific wavelength of light. LED systems have been developed to capitalize on this fact and target mainly wavelength that are necessary for plant growth. We sought to determine if this limited light spectrum would impact the pest population. Preliminary results indicate that the major greenhouse pest *Liriomyza trifolii* (Diptera: Agromyzidae) had reduced mining on both chrysanthemum (*Chrysanthemum sp.*, Asterales: Asteraceae) and gerbera daisy (*Gerbera sp.*, Asterales: Asteraceae) under LED light systems when compared to HPS lighting.

Keynote Talk

Developments in the “standing army approach” for biological pest control in protected crops

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Abstract: Creating a “standing army” of natural enemies is not a new idea in biological control. In fact, the most robust biocontrol systems are based on the establishment of natural enemy populations before pest arrival. However, lack of food sources, shelter or oviposition sites, and unsuitable microclimate may hamper enemy activity in some crops. These problems can be solved by selecting new enemy species that are better adapted to the crop and/or by providing them needed resources. Here we present results that may contribute to this “standing army approach” in biocontrol. In the first study, we show the importance of acarodomatia for predatory mites. Domatia protect *Amblyseius swirskii* against climatic fluctuations by providing suitable microclimate. Surprisingly, domatia seem to benefit the predators also at high humidity. We discuss the possible function of these domatia and their use to enhance predatory mites in greenhouse crops.

In a second study, foraging of natural enemies on tomato plants, including generalist phytoseiid predatory mites that may control whiteflies, spider mites, thrips and tomato russet mites, is hampered by glandular trichomes that protect the plants from herbivory. We tested whether predator movement could be facilitated by providing ropes or twining plants around the tomato stems and thus improve control of tomato russet mite (*Aculops lycopersici*). The combination of the predatory mite *Amblydromalus limonicus* with jute ropes or the twining plant *Ipomoea purpurea* significantly reduced damage by tomato russet mites more than predators alone. The best results were achieved with the twining plants; these plants not only function as a “highway” for the predatory mites, but also provide prey to the predators. Our third example involves the selection of new generalist predatory bugs for aphid control in sweet pepper. Current aphid control is based mainly on specialist natural enemies that do not establish in the absence of aphids. We aimed to select aphid predators that are able to establish on sweet pepper plants before aphids arrive. We selected four species of zoophytophagous mirid predators that feed on both plant and prey: *Macrolophus pygmaeus*, *Dicyphus errans*, *Dicyphus tamaninii* and *Deraeocoris pallens*. None of the predators was able to control an established population of aphids on sweet pepper plants. However, *M. pygmaeus* and *D. tamaninii* successfully reduced aphid populations when released prior to artificial introduction of aphid onto the plants. Yet best results were achieved with *M. pygmaeus* in combination with a weekly application of supplemental foods (sprays of sterilized eggs of the flour moth *Ephesia kuehniella* and decapsulated cysts of the brine shrimp *Artemia franciscana*).

These examples show how biological pest control could be enhanced by selecting natural enemies that are able to survive in crops in the absence of target pests and by providing them with resources that enhance their survival and reproduction in the crop.

Endophyte induced plant responses enhance whitefly control in tomato by *Macrolophus pygmaeus*

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Abstract: Fungal endophytes can have significant effects on the growth and survival of herbivores either directly through changes in plant chemistry, or indirectly through changed performance of their natural enemies that suffer from fungal- or plant-derived secondary metabolites in their host or prey. In case the natural enemy is an omnivore that feeds both on the plant and the herbivore, effects may be more complicated, since the endophyte can affect the omnivore both through changed quality of their prey and the plant. Here we studied how a non-pathogenic strain of *Fusarium oxysporum* (Fo162) mediates interactions between the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), and the omnivorous predator *Macrolophus pygmaeus* (Rambur) on tomato plants. The effect of the endophyte Fo162 on greenhouse whitefly population dynamics was tested both in the presence and in the absence of the predator *M. pygmaeus* in a greenhouse trial on tomato plants. Whiteflies were, in contrast with earlier studies, not significantly affected by the endophyte in the absence of the predators, but densities were significantly lower on tomato plants with the endophyte and *M. pygmaeus* than on plants with only *M. pygmaeus*. Population densities of the predators were not different between endophyte treated and untreated plants. This suggests that the endophyte forced the predators to shift more from plant feeding to prey feeding. Experiments without whiteflies confirmed that the endophyte has a negative effect on the survival and reproduction of the predators, but this could easily be compensated by providing an alternative food source. Hence, we think that endophytes can be a useful tool to increase pest control and possibly reduce plant damage by omnivorous predatory bugs.

Invited Talk

How biostimulants help to grow more with less

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Abstract: *Transition* – Our world is in transition, and this effects agriculture in several ways. Global warming influences distribution and development of pests and diseases. Bigger extremes in climate (hot/cold; wet/dry) and salinization are increasingly sources of abiotic stress. Number of active ingredients against pests and diseases decreases as pathogens develop resistance. Consumer and organizations become increasingly critical on chemical residues. Retail imposes below -legal Minimum Residue Levels on producers, meanwhile gains the biggest added value in the chain and does not give producers room to excel in product quality. Growers who manage to escape the anonymity in the traditional chain manage to get quality financially rewarded.

Paradigm shift – Agriculture and pest management need a paradigm shift from *control* to *adaptation*, in order to be able to do more with less; shift from controlling problems to growing plants less attractive to biotic stressors. There is a long list of frameworks and initiatives addressing this issue: Sustainable intensification (FAO), Agroecology, Fertiplus (EU), Organics, Natural Growing, etc. Biostimulants play an important role here. These inputs have long been used, but yet little researched. The European Biostimulant Industry Council (EBIC) promotes the contribution of plant biostimulants to make agriculture more sustainable and resilient. It was founded in June 2011 and gained legal identity in 2013. The actual market for biostimulants measures 1.3 billion € and is expected to double in coming 5 years (compare pesticides ~\$50 billion in 2013). Leading chemical companies make acquisitions in the biostimulant sector.

Biostimulants – Plant biostimulants contain substances and/or micro-organisms whose function, when applied to plants or the rhizosphere, is to stimulate natural processes to enhance nutrient uptake, nutrient efficiency, tolerance to abiotic stress, and crop quality. Important biostimulant categories are humic/fulvic acids, amino acids, seaweed/kelp extracts, micro-organisms and some other substances. Most biostimulant products are complex and better be characterized by their effects than by their composition. Some important modes of action are: triggering induced resistance, generating stronger plant cell, creating biodiverse suppressive soils, influencing plant morphology via plant hormone balance. To gain benefit, growers have to adopt a more proactive approach and learn to apply biostimulants correctly, and obtain advisors' support.

Successes and failures – Growers of a range of crops in different climate zones have successfully used biostimulants to improve their profits. Either through achieving lower pesticide use, better pest/disease control, higher nutrient efficiency, higher production, better quality and/or lower labor costs. Expertise in plant physiology, soil science, microbiology and pest & disease management must be merged on a practical level to reap the benefits and make biostimulants an interesting tool for all stakeholders.

Attractiveness and suitability of alternative plants for the omnivorous mirid *Nesidiocoris tenuis**

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Abstract: The role of generalist predators in agricultural pest management is increasingly strengthened, because there is good evidence of their efficiency as biocontrol agents. Besides, these predators are able to feed on various non-pest food substrates, such as pollen, nectar and plant sap of wild and cultivated plants. *Nesidiocoris tenuis* (Reuter) (Hemiptera: Miridae) is an important biocontrol agent of several key arthropod pests; however, in tomato crop this generalist predator can cause economic damage owing to its herbivory .

We investigated under laboratory conditions the influence of two alternative plants, *Dittrichia viscosa* L. (Asteraceae) and *Sesamum indicum* (L.) (Pedaliaceae), with or without prey, on *N. tenuis* damage and its biological control services on *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) eggs. Both *D. viscosa* and *S. indicum*, tested as companion plants in dual choice bioassays, significantly reduced the damage of the mirid on tomato plants. *Sesamum indicum* was more attractive than *D. viscosa* for feeding and oviposition and its presence did not interfere with the predation on *T. absoluta* eggs. We also studied the potential of the two alternative plants, compared to tomato, as preyless rearing substrates for the mirid, and only *S. indicum* showed to be a suitable host plant for *N. tenuis* development and oviposition.

Olfactory trials were conducted to evaluate the attractiveness of volatile compounds emitted by the tested plants. Alternative plants and tomato plants, both healthy and infested with eggs or larvae of *T. absoluta*, were exposed to *N. tenuis* females. The data collected confirmed the significantly higher attractiveness of *S. indicum* both compared to *D. viscosa* and to tomato. Besides, the presence of both tested pest instars did not significantly increase the tomato attractiveness towards the predator, suggesting a prevalent herbivorous behavior of this zoophytophagous insect. Field trials were performed in 2013 in an organic farm in order to assess the role of sesame in attracting *N. tenuis* and in reducing its damage. The results obtained confirm the laboratory data on plant attractiveness.

Overall, this research suggests that *S. indicum* can be successfully employed in Integrated Pest Management programs in tomato as mass rearing, trap and/or banker plant .

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Additive and synergistic interaction amongst *Orius laevigatus*, Entomopathogens and Neem for Western Flower Thrips control

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Abstract: There is a global tendency towards reducing the use of synthetic pesticides because of the associated problems of resistance, environmental contamination, adverse effect on non-target organisms and demand for pesticide-free foods. This has stimulated the search for novel and diverse control strategies as in the case of western flower thrips (WFT), a deleterious pest in several horticultural crops. However, when WFT occurs in high densities and continuously, use of a single biocontrol agent may not ensure fast and reliable control. The use of soft selective biopesticides for fast knock down effects in combination with slow reacting but persistent biocontrol agents may be a sustainable solution. Moreover targeting specifically foliage- and soil-dwelling life stages may enhance control efficacy. Hence, this study evaluated the interaction among the foliage-dwelling predator *Orius laevigatus*, and soil applied entomopathogens and neem for the control of WFT. The predator *Orius laevigatus* (Fieber) Re-natur was introduced at different rates and also targeted different life stages of WFT. Commercially available biocontrol products evaluated for soil treatment were *Steinernema carpocapsae* (Weiser) Nemastar®, and a non commercial isolate of *Metarhizium anisopliae* (Metschnikoff) Sorokin ICIPE-69 and Neem Azal-T solution. Interactions among the treatments were mostly additive except of two (*Orius* + Neem and *Orius* + *M. anisopliae* ICIPE-69 + *Steinernema carpocapsae*) showing synergistic responses. Efficacy against WFT was significantly improved when the treatments were combined achieving 83-97% reduction in WFT emergence, compared to reductions of 45-74% in the single treatments. Significant differences were observed between efficacy of *Orius* and *M. anisopliae* as well as among combinations with and without *Orius spp.* A total reduction of 93-99.6% in survivals was recorded for the fungi based treatments when secondary mortality due to mycosis was taken into account. The additional benefit of releasing two predators (86-96% reduction) instead of just one (76-88%) was negligible. When *Orius* was introduced to target larval stage 1 of WFT, 96-98% reduction was achieved while only 71-89% was recorded while targeting larval stage 2. Early release of *O. laevigatus* either alone or in combination with soil application of neem and entomopathogens is key to successful biocontrol of thrips.

Keynote Talk

Managing Invasive Species in the Greenhouse and Nursery: A Comprehensive Systems Approach

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Abstract: The greenhouse industry (vegetables and flowers) and the nursery industry are an increasingly important component of California agriculture. Vegetable production has enjoyed a long history of practical biological control emanating from advances made in Europe and in the Mediterranean area. This is in contrast to ornamental production (nursery and flowers) that has been slower to adopt this pest control strategy. Nonetheless, biological control has advanced in all these production systems in the state and much of this has been made possible by a commercial insectary industry that provides active advising and quality natural enemies. A complex of natural enemies is available to control most of the pests encountered. Impediments to the greater adoption of biological controls exist and there are areas where more research is needed. For example, although native natural enemies commonly migrate into greenhouses (in the absence of sprays), their overall contribution to pest control is poorly understood. Inexpensive and relatively safe, pesticides and biopesticides are widely used by the greenhouse/nursery industry and research is needed to more effectively integrate them with natural enemies. Invasive species continue to be the bane of established IPM and biological control programs across many commodities in the state, and this is especially true for the nursery industry. Given how the ornamental industry is dependent on propagating and shipping plant material in and out of California, the quarantine reality associated with invasive species often impacts nursery/greenhouse producers through increase in pesticide application that reduces the opportunity for biological control. In order to decrease the confusion surrounding management of multiple invasive species, on line tools that provide information on best management practices have been developed. In addition, a systems approach based on a hazard analysis of critical control points has been proposed as a method for growers to develop production practices that are more resilient to invasive species. Finally, research is ongoing to improve overall plant health through better management and understanding of the rhizobiome that also may make the system refractory for invasive species. Each of these strategies will be reviewed.

Biological control of the red spider mite in tomatoes under arid and semi-arid conditions in Israel.

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Abstract: The red spider mite, *Tetranychus urticae*, is one of the most devastating polyphagous pests world-wide. In protected tomato cultivations in Israel it is the most difficult pest to control due to its rapid development of resistance to acaricides. Climatic conditions of the main cultivation area are favorable for mite development year round. The common practice of tomato growers is to spray every 7-10 days using different chemicals to control spider mites, yet in many plots significant damage and loss of yield is recorded. Here we report on implementation of biologically-based IPM program which involves weekly scouting and releases of the predatory mite *Phytoseiulus persimilis* Athias-Henriot (Acari: Phytoseiidae) that resulted in 80% decrease in acaricide use and improved control of the pest. During two consecutive seasons we compared the efficacy of spider mite control between IPM-biocontrol treated plots and chemically treated plots. The chemically-treated plots used 4 times more acaricides than the IPM-treated-plots. Nonetheless, the spider mite load (calculated as the number of spider mites per area X number of days that spider mites were present in that area) was three times higher in the chemically-treated plots. These results, coupled with commercial and technical field experience of the last three years, confirm that implementing *P. persimilis* in tomato crop and making decisions based on sophisticated scouting, yield a safer and more potent system to control spider mites.

On the interplay between omnivores' behavior and the nutritional value of plant and prey foods

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Abstract: Consumers require a specific balance of nutrients to survive, develop and reproduce. Most insect species constitute a nutritionally-imbalanced foods, forcing their predators to regulate nutrient intake to match their physiological requirements. Omnivory could be one of the possible mechanisms for nutrient regulation.

Many natural enemies used in biological control programs are true omnivores that supplement their prey-rich diet with plant materials. We examined the nutrient composition of plant and prey foods and their suitability for the omnivorous mite, *Amblyseius swirskii* (Acari: Phytoseiidae), and tested whether switching behavior, i.e. omnivory, is used to regulate nutrient intake and increase omnivore's fitness.

We examined the fecundity of females when fed pepper pollen or prey found in pepper crops in the Arava valley, Israel (*Bemisia tabaci*, *Tetranychus urticae* and *Frankliniella occidentalis*). Additionally, females were offered pollen from two other plants, *Typha* sp. and *Zea mays* that may serve as food supplements for the omnivorous mite. Results show that females deposited more eggs when fed *Typha* or *Z. mays* pollen than any of the prey species or pepper pollen. Thus, the nutrient composition of the prey and pepper pollen available in pepper crops are inadequate for mite reproduction.

To identify the nutrients that render these prey unbalanced for the mites, we explored their nutritional compositions. Analyses revealed that overall, pollen has a higher sugar content (23-40%) than prey (0.7-2.2%), but the percentage of protein is higher in prey (~50%) than in pollen (16-20%). Therefore, we hypothesized that the recorded discrepancies in sugar and protein content encourage the omnivore to switch between pollen and prey in order to balance its nutrient intake.

The benefit of switching was tested by offering female mites that were fed a pre-treatment diet of *Typha* pollen or *F. occidentalis* larvae for 5 days, the same or the alternative food for 4 additional days. We found that switching from plant to animal food and vice versa resulted in a higher female fecundity than consuming the same diet without switching. The contribution of diet switching to female fecundity was especially strong when females switched from prey to pollen diets. It appears therefore that switching allows omnivores to regulate their nutrient intake and thus achieve higher performance. Using an ordinary differential equation model we show that nutrient-specific foraging may destabilize omnivore-prey population dynamics, depending on the degree to which the omnivore alters its foraging in an attempt to balance its nutritional state.

The consumption of prey and plant foods by omnivorous coccinellid beetles: performance and feeding choice

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Abstract: A growing body of literature indicates that many arthropods feed on both prey and plant-provided foods. Some of these omnivorous consumers gain fitness benefits by feeding on plant-provided resources that supplement their prey-based diet. Other species however, use prey and plant materials as alternative foods. In the present study, we investigated the alternative and supplementing role of plant materials for two primarily predacious coccinellid species that differ in morphology, demography and ecology.

We found that in the absence of prey, the two ladybeetle species, *Coccinella septempunctata* and *Hippodamia variegata*, are able to sustain themselves on *Brassica napus* pollen alone. This enables them to persist in agricultural crops when prey is scarce and prevent subsequent pest outbreaks. Moreover, a mixed diet of prey and pollen increased the survival of *H. variegata* larvae and oviposition by *C. septempunctata* females by approximately 1.6 fold, compared to a prey-only diet. Finally, *C. septempunctata* larvae fed previously only on prey, preferentially devoted more time to pollen feeding; such compensation for diet deficiencies was not detected in pollen-fed larvae. A similar shift to redress dietary deficiencies was not recorded for *H. variegata*.

Taken together, results indicate that pollen serves not only as an alternative food source, but as a beneficial supplement to prey diet for both ladybeetle species. In addition, and under certain conditions, individuals may shift between the two food sources, perhaps to redress nutritional deficits and obtain an optimal, balanced diet. Conclusions from the present study have important implications for the addition of pollen supplements both during mass rearing and under natural crop conditions to enhance the efficiency of the two ladybeetle species as natural enemies of agricultural pests.

Developing environmentally safe control methods for *Fusarium oxysporum* for the prevention of bulb mite damage in onion

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Abstract: The bulb mite *Rhizoglyphus robini* Claparède (Astigmata: Acaridae) is a pest of Liliaceae, vegetables, cereals and storage ornamentals. In Israel it attacks onion, garlic, lily and ruscus (*Danae racemosa*). Damage has been attributed to the mite itself and to the combined effects of the mite and fungal pathogens infecting various crops. In Israeli garlic and onion fields the bulb mite is treated as a pest in its own right, even though it is always found in association with fungal pathogens. Accordingly, plant protection recommendations are to treat onions as soon as bulb mites are discovered. In a recent study we demonstrated that bulb mites were attracted to *Fusarium oxysporum* and mite fecundity was 6 times higher on onion sprouts infested with the fungus. Additionally we showed that the bulb mite would not attack germinating onion seeds not infested with *F. oxysporum*. For many years greenhouse and field crops were protected against soil fungi and arthropod pests by soil-sterilizing chemicals, but this approach is now being phased out, because these pesticides are highly toxic and pose a serious environmental risk. Solar sterilization, by mulching with polyethylene sheets, developed to suppress pathogens, such as *Verticilium dahliae* and *F. oxysporum* f.sp. *lycopersici* was also effective against bulb mites at depths of 10, 20, 30 cm underground. While this approach is more environmentally safe, it was less effective and like the first method, kills beneficial soil organisms along with the pests. An alternative approach developed to control soil pathogens is through suppressive soils using composts. Adopting this methodology could lower inoculum pressure of pathogenic fungi, thereby reducing the attraction of the plant material to *R. robini*. Another environmentally safe method is the biocontrol of *F. oxysporum* with antagonistic bacteria. The aims of the present ongoing study are: 1) To determine the feasibility of suppressing *F. oxysporum* with compost and or bacteria. 2) Assuming this suppression can be attained, to assess its effect on the prevention of bulb mite damage. The proposed methodology for this three year study, initiated in 2015, will be presented in the poster session.

Effect of wild and commercial tomato plants on *Tuta absoluta* and its omnivorous predator *Nesidiocoris tenuis*

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Abstract: Plant domestication and the selection for higher yields and desirable agronomic traits often increase plant suitability for herbivores. These processes may also affect the ability of natural enemies to suppress pests on susceptible plants. We hypothesized that (a) Plant domestication is associated with reduced plant defense against herbivorous insects; (b) Much like herbivores, omnivorous consumers are also impacted negatively when feeding on resistant plants; and (c) The presence of prey on resistant plants alters oviposition site selection by omnivores.

We tested these hypotheses using domesticated and wild tomato genotypes, the pestiferous moth *Tuta absoluta* (TA), and its omnivorous predator *Nesidiocoris tenuis* (NT) that also feeds on tomato plants.

We compared TA and NT preference for and performance on a commercial cultivar (Avigail 870) and five wild tomato species (*Lycopersicon pennellii*, *L. hirsutum* f. *typicum*, *L. peruvianum*, *L. pimpinellifolium* and *L. neorickii*) in laboratory experiments.

Results indicate that the wild species *L. pennellii* was the least preferred by TA for oviposition. Likewise, TA pupal weight was lower and adults were smaller on *L. pennellii* and *L. hirsutum* compared to the commercial cultivar. In addition, larval developmental rate and survival were lower on *L. hirsutum*. NT, on the other hand, preferred to oviposit on the TA-resistant *L. hirsutum*. Nevertheless, NT developmental rate and adult size did not differ among tested tomato genotypes. Yet in the absence of prey, NT had higher nymph survival on the TA-resistant *L. hirsutum*. In the presence of prey however, nymph survival had increased significantly on all plant species; the differences recorded in the absence of prey had now disappeared.

In conclusion, domesticated plants are not necessarily more susceptible to herbivory than their wild predecessors; herbivores and omnivores may be affected differently by their shared host plants; and the presence of prey may alter omnivore's oviposition preference.

Invited Talk

Prospects & challenges in practicing biologically-based IPM under arid & semi-arid conditions: A biocontrol producer's perspective

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Abstract: In Israel, a fully commercial IPM-biocontrol program is run in ca. 2,000 hectares of protected sweet pepper, 300 hectares of strawberries in low tunnels and 150 hectares of protected tomatoes. The biological "bundle" comprises the predatory mite *Phytoseiulus persimilis* against spider mites; the minute pirate bug *Orius laevigatus* to fight western flower thrips; the parasitic wasp *Aphidius colemani* to control the cotton aphid and the green peach aphid and the predatory mite *Amblyseius swirskii* to control sweet potato whitefly. These natural enemies are accompanied with intensive technical advice on a weekly basis throughout the entire cropping season.

Arid conditions characterize the greenhouse production along the eastern valleys of Israel: Jordan Valley and Arava Valley, whereas semi-arid environment prevails mostly along the coastal plain. Both climatic zones pose particular challenges in implementing biologically-based IPM. (i) Heat spells, frequent during the intermediate seasons (spring and autumn), hinder establishment of *P. persimilis* and *A. colemani*; (ii) Dry eastern winds, especially during autumn, bring the micro relative humidity to a level which is favorable to spider mites and at the same time detrimental to *P. persimilis*; (iii) High risk of Tomato Spotted Wilt Virus (TSWV) transmitted by western flower thrips, especially in the semi-arid region; (iv) Cold chain logistics of the natural enemies' delivery. A necessity during periods of high temperature.

Technical/practical solutions are described for each of the aforementioned challenges within the context of a robust and reliable IPM-biocontrol program. These are tailored to the growers in each climatic region.

Efficacy of pyrethroid-impregnated nets in reducing impact of pests on vegetable crops

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Abstract: Invasive insect pests represent one of the most serious threats to modern agriculture and for their control, increasing attention is paid to new physical, biotechnical and chemical measures with low non-target effects. Among the available practices and technologies included in Integrated Pest Management (IPM) strategies, insect-proof nets are commonly used as physical barriers for preventing crop damage in protected cultivation systems. They reduce both pest populations and the possibility of transmission of insect-borne diseases, vectored mostly by aphids, thrips and whiteflies. In this study, we aimed at improving the insect-proof effectiveness in controlling three key horticultural crop pests. We tested the insecticidal potential of long lasting pyrethroid-impregnated nets in the laboratory. In choice and no-choice bioassays, using tomato and cabbage plants, we tested the irritant, repellent and sublethal effects of α -cypermethrin-impregnated net on adults of *Tuta absoluta* (Meyrick) (Lep: Gelechiidae), *Bemisia tabaci* (Gennadius) (Hem: Aleyrodidae) and *Myzus persicae* (Sulzer) (Hem: Aphididae). Pyrethroid-treated nets showed to irritate the cotton whitefly *B. tabaci* and the aphid *M. persicae* causing an increased mobility, and repellent in reducing the rate of crossing through the impregnated net compared with untreated net. For *T. absoluta*, we saw that the treated net repellence is exerted only after contact and not through volatile cues. More importantly, chronically exposed adult moths suffered major sublethal effects on their reproduction. These results show the possibility to combine physical and chemical protection against these major horticultural pests, thus optimizing integrated pest management programs for meeting the standards of safety and environmental quality.

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High temperature performance of *B. tabaci* parasitoids

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Abstract: Greenhouse cultures typically afford a special climate for the plants and the insects that reside inside. This includes escape from extreme cold and, usually a favorable, moderate temperature around 25-27°C. However, occasional high external temperatures, especially in warmer climates, like in the Mediterranean region, may cause a temporary rise to high levels, exceeding 30 °C for limited times. Such a rise affects the whole system and may cause an upset in a generally favorable balance between the natural enemies and the pest. In the case of *Bemisia tabaci*, that may respond positively to high temperatures, the pest may escape the control by enemies and become seriously pestiferous.

Therefore, it is useful to know how the different natural enemies respond to temporary high temperatures. In our studies we examined high temperature reaction of two parasitoid species, *Eretmocerus hayati* Zolnerowich & Rose and *Encarsia sophia* (Girault & Dodd). The experiment was conducted out-of-doors with whitefly-infested cotton plants that were kept in circular cages and started in 2012 with *E. hayati*. The control cages were covered with nylon mesh whereas those with the elevated temperature had extra plastic sheets around, causing the temperature to rise by an average of about 2.2 °C.

The results showed that the number of nymphs and adults of *B. tabaci* increased under elevated temperature, while the number of *Er. hayati*, the parasitism rate, as well as the synchrony between *B. tabaci* and *Er. hayati* decreased and the sex ratio became more female biased.

In the next year, both *Er. hayati* and *En. sophia* were released in a similar experiment in circular cages in the field, in five different combination rates. In contrast to *Er. hayati*, *En. sophia* population size and parasitism rates were higher under the higher temperatures as compared to *Er. hayati*. Likewise, the treatments with higher proportion of *En. sophia* reduced more whitefly population as compared to the ones with higher numbers of *Er. hayati*.