



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

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Promoting integrated pest management in protected crops in a changing Europe and Mediterranean basin



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BOOK OF ABSTRACTS



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¹*High Agronomic Institute of Chott-Mariem (ISA-CM), Sousse, Tunisia;* ²*IRTA - Institute of Agrifood Research and Technology, Spain;* ³*INRAE - National Research Institute for Agriculture, Food and Environment, France;* ⁴*The Hebrew University of Jerusalem, Israel;* ⁵*Faculty of Agrobiotechnical Sciences Osijek, Croatia;* ⁶*Instituto Superior de Agronomia, Universidade de Lisboa, Portugal;* ⁷*PCS, Ornamental Plant Research, Belgium;* ⁸*Çukurova University, Adana, Turkey;* ⁹*Wageningen University, The Netherlands;* ¹⁰*Biotechnical Faculty, University of Montenegro;* ¹¹*Democritus University of Thrace, Greece;* ¹²*Instituto de Biología Molecular y Celular de Plantas, Universitat Politècnica de València, Spain;* ¹³*Faculty of Agriculture, University of Belgrade, Serbia;* ¹⁴*Departamento de Agronomía, University of Cordoba, Spain;* ¹⁵*Di3A, University of Catania, Italy;* ¹⁶*Institut of agriculture and forestry, Nova Gorica, Slovenia;* ¹⁷*DISAFA, University of Torino, Italy;* ¹⁸*Biotechnical Faculty, University of Ljubljana, Slovenia;* ¹⁹*Institute for Adriatic Crops and Karst Reclamation, Split, Croatia.*

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Keynote lectures

Challenges and opportunities of utilization of biological control against regulated pests of protected crops in the EPPO region

Rob Tanner

European and Mediterranean Plant Protection Organization, Paris, France

Abstract. Biological control is a pest management method that can offer an alternative to chemical pesticides. With a proven safety record, it can be used against indigenous and non-indigenous pests within protected conditions or in open field cropping systems. The European and Mediterranean Plant Protection Organization (EPPO) is an international organization responsible for cooperation and harmonization in plant protection within the European and Mediterranean region. The Joint EPPO/IOBC Panel on biological control agents (BCAs) has developed Standards on the safe use of biological control. These aim to harmonise approaches for the introduction of BCAs across the region and to promote increased utilization of biological control against regulated pests in the EPPO region. PM 6/1 *First import of non-indigenous biological control agents for research under confined conditions* and PM 6/2 *Import and release of non-indigenous biological control agents* provide guidance to relevant national authorities on the first import, and release of BCAs, and on general safeguarding measures to be applied during these processes. To help users make decisions on import and releases of BCAs, the Standard PM 6/4 *Decision-support scheme for import and release of biological control agents of plant pests* has been developed. It provides guidance on a risk/benefit assessment of BCA releases. The EPPO Standard PM 6/3 *Biological control agents safely used in the EPPO region* provides a list of BCAs which are already present in the EPPO region and have been safely used without negative non-target effects. EPPO recommends its countries to use a simplified procedure of decision making for these BCAs. This presentation will discuss these Standards and also note other challenges and opportunities in the utilization of biological control against regulated pests of protected crops.

Key words. Augmentative biological control, invertebrate pests, Joint EPPO/IOBC Panel on biological control agents, regional guidance.

Aphid parasitoids taxonomy and new resources for biological control

Željko Tomanović^{1,2}

¹ Institute of Zoology, Faculty of Biology, University of Belgrade, Studentski trg 16, 11000 Belgrade, Serbia

² Serbian Academy of Sciences and Arts, Knez Mihailova 35, 11000, Belgrade, Serbia

Abstract. Many species of aphid parasitoids (Hymenoptera, Braconidae, Aphidiinae) are important biological agents and economically important natural enemies of aphids in various agroecosystems. Aphid parasitoids are a common model for studying changes in biodiversity and the effects of biological control in crop-dominated landscapes in Europe, including the Mediterranean region. Several species of aphid parasitoids are commercially produced and available on the market. Modern production technologies allow low costs for mass production, but we need a wider variety of products. Due to frequent cases of cryptic speciation and lack of taxonomic expertise, our knowledge of many economically important species of aphid parasitoids and even of commercially produced species is not satisfactory. However, an integrative approach combining morphological traits, host range patterns and molecular markers is leading to an expansion of our basic taxonomic knowledge, which should result in more commercially available aphid parasitoid species on the market and more diverse products for biological control in general and in the Mediterranean region.

Among the most important are the species of the *Aphidius colemani* group, which are widely used as biological control agents in greenhouses and have been commercially produced in Europe since 1992. The species group *Aphidius eadyi* is used worldwide to control *Acyrtosiphon pisum* Harris and *A. kondoi* Shinji in the field. Our research confirmed the existing cryptic species within these species complexes. We also discussed and discovered new aphid parasitoid species from different crops (soybean, wheat, fruit and vegetable crops). Successful biological control requires the use of different parasitoid biological agents to cover a broad spectrum of aphid pests under variable (micro)climatic conditions.

Key words. Aphid parasitoids, integrative taxonomy, cryptic species, biological control.

Holistic and sustainable approaches for pest and stress management in horticultural crops

Alberto Urbaneja¹, Meritxell Pérez-Hedo²

¹ Instituto Valenciano de Investigaciones Agrarias (IVIA). Centro de Protección Vegetal y Biotecnología. CV-315, Km 10.7, 46113 Moncada, Valencia, Spain

² Instituto de Biología Molecular y Celular de Plantas (IBMCP), Consejo Superior de Investigaciones Científicas, Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain

e-mail address: urbaneja_alb@gva.es

Abstract. The growing impact of climate change, biodiversity loss, and escalating pest pressures poses a major challenge to agricultural sustainability, highlighting the need for holistic and sustainable crop protection strategies. This lecture explores an integrated approach to enhancing crop resilience through biodiversity conservation, biological control, and plant defense activation. While previous studies have demonstrated the effectiveness of these strategies individually, our research group is now assessing their combined impact in various horticultural contexts. Companion planting is key in fostering functional biodiversity and enhancing natural enemy populations. In tomato crops, intercropping *Fagopyrum esculentum* and *Tordylium officinale* has been shown to reduce infestations of two major tomato pests, *Bemisia tabaci*, and *Tuta absoluta*, while simultaneously increasing populations of the zoophytophagous predator *Nesidiocoris tenuis* and overall biodiversity. This demonstrates its potential to balance pest control with crop productivity. Beneficial fungi, such as *Trichoderma afroharzianum* T-22, have been evaluated under water stress conditions in combination with *N. tenuis*. Our findings indicate that *T. afroharzianum* enhances plant growth, mitigates oxidative stress, and reduces *N. tenuis*-induced plant damage, underscoring its role in strengthening plant resilience to biotic and abiotic stressors. Additionally, defense elicitors, particularly Herbivore-Induced Plant Volatiles (HIPVs), are being investigated for their potential to reduce pesticide dependence. In tomatoes, (Z)-3-hexenyl propanoate (Z-3-HP) has been shown to enhance resistance against key pests while minimizing *N. tenuis*-induced damage. In sweet peppers, HIPV exposure upregulates key defense genes, reduces infestations by *Frankliniella occidentalis* and *Trialeurodes vaporariorum*, and attracts beneficial predators such as *Orius laevigatus*.

This presentation will discuss the potential for integrating these strategies to develop a holistic pest and stress management approach in horticultural crops. Integrating biodiversity-driven approaches, including zoophytophagous predators, beneficial fungi, and plant defense elicitors, offers a pathway to more sustainable agricultural practices that strengthen resilience, improve productivity, and contribute to global food security.

Key words. Companion plants, Miridae, beneficial fungi, Herbivore-Induced Plant Volatiles (HIPVs), Plant resilience.

Oral presentations

Development of an adapted biocontrol-based program for *Scirtothrips* control in Strawberry

F. Javier Calvo, José M. Moreno, Juan J. Liria, José E. Belda

Koppert Biological Systems. Cobre 22 St., 04745 La Mojonera, Almeria, Spain

Abstract. Strawberry crops are affected by several thrips species in the Mediterranean region, among which *Frankliniella occidentalis* has been typically the most important. This pest has been successfully controlled by releasing the anthocorid bug *Orius laevigatus*. However, over the last years, two species of the genus *Scirtothrips*, i.e. *S. aurantii* and particularly *S. dorsalis*, have become quite important due to the severe fruit damage they can provoke when feeding and the subsequent economic losses for growers. Unfortunately, *O. laevigatus* was found not to be able to provide good control of these pests by itself, and thus the existing biocontrol-based IPM program needed to be improved. Consequently, we initiated a research project aimed at developing an effective biocontrol-based program for the control of these pests. Here we present the results that were used to develop this program, which demonstrated that the combination of phytoseiid mites with *O. laevigatus* can be an effective and sustainable alternative to the pesticide use for the control of thrips pests in strawberry crops.

Key words. Anthocoridae, Phytoseiidae, Thripidae, Biological control.

Populations of thrips and their potential natural enemies in sweet pepper greenhouses in southeast Spain

Michelangelo La-Spina, Eulalia Martínez-Díaz, Elena López-Gallego, Juan Antonio Sanchez

Equipo de Control Biológico y Servicios Ecosistémicos, Instituto Murciano de Investigación y Desarrollo Agrario y Medioambiental (IMIDA), C/ Mayor s/n, 30150 La Alberca (Murcia), Spain

e-mail address: michelangelo.la@carm.es

Abstract. *Frankliniella occidentalis* and *Thrips parvispinus* are significant pests affecting sweet pepper crops in commercial greenhouses. Since the introduction of *T. parvispinus*, this species has become an increasingly severe problem in the Campo de Cartagena region, Murcia, Spain. This pest primarily causes substantial damage to plants, including fruit and leaf deformations. In response to industry demands for effective management, this study aims to review current control strategies and analyze thrips and their potential natural enemies populations on the crop. A comprehensive survey was conducted from spring 2024 to summer 2025 in commercial sweet pepper greenhouses to monitor thrips populations and their associated natural enemies. The presence of *Lobularia maritima*, as banker plant, within greenhouses, as well as shrubby field margins nearby, was examined as potential factors influencing these populations on the crop. The findings indicate that both thrips and natural enemy populations are affected by these structural elements. Fruit and leaf deformities were more pronounced in the absence of banker plants and natural field margins. Moreover, *T. parvispinus* populations were notably higher in greenhouses lacking these structural elements. Among the natural enemies identified, *Orius* species were the most abundant, followed by phytoseiid mites, coccinellids, and mirids. These observations provide valuable insights to enhance current biological control strategies against thrips in sweet pepper cultivation.

Key words. Biological control, banker plants, field margins, biodiversity.

Evaluation of natural enemies against tobacco thrips *Thrips parvispinus* (Karny)

Juliette Pijnakker, Dominiek Vangansbeke, Irma Iemma, Sam Dubbeldam, Rob Moerkens, Felix L Wäckers

Biobest N.V., Ilse Velden 18, B-2260 Westerlo, Belgium

Abstract. The tobacco thrips, *Thrips parvispinus* (Karny), is an emerging threat to greenhouse horticultural crops worldwide. Laboratory trials revealed that the predatory mites *Amblyseius swirskii*, *Amblydromalus limonicus*, and *Transeius montdorensis* could kill *T. parvispinus* eggs. Gravid females of *A. swirskii*, *A. limonicus*, *Neoseiulus cucumeris*, and *T. montdorensis* consumed 2–3.5 first-instar larvae per day, though predation rates were lower compared to those on *Frankliniella occidentalis* (western flower thrips). However, in a commercial *Ficus elastica Robusta* crop, weekly introductions of *A. swirskii* and *N. cucumeris* failed to provide sufficient control. Larger generalist predators such as *Chrysoperla carnea* (lacewing), *Franklinothrips vespiformis* (predatory thrips), and predatory bugs (*Orius laevigatus* and *Macrolophus pygmaeus*) were also tested. Trials with *C. carnea* and *F. vespiformis* in a commercial *Ficus* greenhouse achieved population reductions but not eradication. An integrated pest management strategy combining preventative releases of predatory mites, larger generalist predators, and alternative food sources is proposed for managing tobacco thrips in vegetable crops. In ornamental plants, predator establishment remains limited, necessitating repeated releases. Further research is essential to optimize combinations of predatory mites, generalist predators, and biopesticides to enhance control strategies for *T. parvispinus*.

Key words. Thrips, natural enemies, greenhouse, ornamentals.

Exploring the potential of phytoseiids species and the minute pirate bug, *Orius laevigatus*, to control *Thrips parvispinus* in sweet pepper

Sarra Bouagga¹, José Eduardo Belda¹, Thomas V. M. Groot²

¹ Research and development Koppert Spain S.L. Calle Cobre 22, 04745 - La Mojonera, Almeria

² Koppert, Berkel en Rodenrijs, The Netherlands

Abstract. Biological control (BC) in Spanish sweet pepper cultivation has traditionally relied on the release of *Orius laevigatus* and *Amblyseius swirskii* to manage thrips and whiteflies. However, the recent emergence of invasive thrips species, particularly *Thrips parvispinus*, has significantly disrupted the current strategy. This species poses a unique challenge due to its aggressive feeding behavior, rapid spread, and cryptic habits. Consequently, there is an urgent need to identify alternative BC strategies. To address this challenge, this study first evaluated the potential of five predatory mites, *A. swirskii*, *Amblydromalus limonicus*, *Transeius montdorensis*, *Amblyseius cucumeris*, and *Amblyseius andersoni*, under laboratory conditions. Their effectiveness was assessed based on their egg-laying and prey consumption on *T. parvispinus* larvae, compared to a standard prey, *Frankliniella occidentalis*. The results revealed that *A. limonicus* exhibited the highest oviposition and predation, followed by *T. montdorensis* and *A. swirskii*, which performed similarly. In contrast, *A. cucumeris* and *A. andersoni* demonstrated significantly lower effectiveness and were excluded from further testing. Building on these findings, semi-field and field experiments at commercial level were conducted to evaluate thrips control through the preventive release of *A. limonicus*, *T. montdorensis*, and *A. swirskii* alongside *O. laevigatus*. These trials demonstrated a significant reduction in *T. parvispinus* density across all treatments. Notably, treatments involving *A. limonicus* or *T. montdorensis* led to substantially less fruit damage compared to *A. swirskii*. In fact, more than 90% of harvested fruits were classified as marketable in the treatments with *A. limonicus* and *T. montdorensis*, while this percentage dropped to 70% with *A. swirskii* and just 20% in the untreated. These findings underscore the potential of integrating *A. limonicus* or *T. montdorensis* with *O. laevigatus* as an effective biological control strategy for managing *T. parvispinus* infestations in sweet pepper greenhouses.

Key words. *Thrips parvispinus*, predatory mites, *Orius laevigatus*, sweet pepper, biological control.

Investigating IPM tools to manage the invasive mealybug *Phenacoccus solenopsis*

Michele Ricupero¹, Emanuele Porcu², Vincenzo Palmeri², Orlando Campolo², Antonio Biondi¹, Gaetano Siscaro¹, Lucia Zappalà¹

¹ Department of Agriculture, Food and Environment, University of Catania, 95123 Catania, Italy

² Department of Agriculture, University of Reggio Calabria, Feo di Vito, 89122 Reggio Calabria, Italy

Abstract. *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) is a polyphagous invasive pest, native to Asia, that is recently threatening horticultural and ornamental protected crops in Mediterranean countries. Because *P. solenopsis* raises economic concerns, there is a growing interest in exploring sustainable control tools, such as biological control and selective insecticides. After the report of *P. solenopsis* in Italy, predators such as *Cryptolaemus montrouzieri* and *Parexochomus nigripennis* (Coleoptera: Coccinellidae) and parasitoids such as *Anagyrus matritensis* and *Aenasius arizonensis* (Hymenoptera: Encyrtidae) have been recorded as natural enemies of the pest in solanaceous protected crops and ornamental plants in urban environments in Sicily. Because no insecticides are currently authorized on *P. solenopsis* in Europe, we tested several commercial insecticides and plant essential oils (EOs) on the solenopsis mealybug. We also assayed the non-target effects of the most effective synthetic insecticides and EOs against *P. solenopsis* towards *C. montrouzieri* in terms of survival and olfactory response in the laboratory. The host stage selection of *A. matritensis* was assessed on *P. solenopsis* through choice and no-choice tests. Assayed systemic insecticides showed high toxicity towards *P. solenopsis* but negatively affected *C. montrouzieri*, while EOs had a safer ecotoxicological profile. *Anagyrus matritensis* parasitized all *P. solenopsis* stages except the male pupa while the 3rd instar nymph and pre-ovipositing female were the most preferred stages. The results highlighted that careful evaluation of each insecticidal substance should be assessed before its inclusion for the integrated control of *P. solenopsis*. Preliminary data on *A. matritensis* will be useful to unravel the biological traits of this new association and implement potential biocontrol applications. Also the abundant presence in the field of *A. arizonensis* appears promising for *P. solenopsis* biocontrol. Overall, an integrated approach holds significant promise to manage the impact of *P. solenopsis* in new invaded areas.

Keywords. Biological control; botanicals; solenopsis mealybug; ecotoxicology; host stage suitability; mealybug destroyer.

In vitro biocontrol assays of *Spodoptera frugiperda* using indigenous entomophagous fungi from Ivory Coast

Fatoumatou Fofana^{1,2}, Corentin Descombes¹, Assiri Kouamé Patrice², Eric Kwadjo², François Lefort¹

¹ *Plants and Pathogens Group, Research Institute Land Nature Landscape, HEPIA Geneva School of Engineering Architecture and Landscape, HES-SO University of Applied Sciences and Arts Western Switzerland, 150 route de Presinge, 1254 Jussy, Switzerland*

² *Faculty of Natural Sciences, University Nangui Abrogoua, 02 BP 801 Abidjan 02, Cote d'Ivoire*

e-mail address: francois.lefort@hesge.ch

Abstract. The fall armyworm, *Spodoptera frugiperda*, is an extremely polyphagous pest, causing significant damage to maize, tomato and other food crops in Africa and a major threat to Europe, particularly to Southern Europe. Native to tropical and subtropical regions of America, this pest feeds on the leaves and stems of more than 353 plant species and is known for its very high reproductive rate. On the EPPO A2 list for the European Union and A1 list of several European countries, including Switzerland, it has been reported in the 2 past years in Cyprus, Greece, Malta, Portugal and Romania, making it a pest of concern to which we must be prepared. With the objectives to search for efficient alternatives to chemical control products, *S. frugiperda* populations were reared in the Entomology laboratory and tested *in vitro* in the Plant Health Laboratory of the University de Nangui Abrogoua in Côte d'Ivoire for their susceptibility to two isolates of *Metarhizium anisopliae* (namely T331 and T35), 5 isolates of *Metarhizium* spp. (T34, T132, T121, T313, T141) and three isolates of *Beauveria bassiana* (namely A211, A214a et A214b). Fungal spores were applied *in vitro* on third instar larvae of *S. frugiperda* at a concentration of 5×10^6 spores/mL. Larval final mortality rates have been determined at nine days after treatment. Mean lethal times (LT50) were calculated using mortality rates from day 1 to day 9. Isolates of *B. bassiana* A214b, A211 and A214a caused 100% mortality by day 9 and caused LT50 between 1.83, and 3.54 days. The 5 *Metarhizium* spp. isolates caused mortalities ranging from 86.66% to 93.33% with LT50 ranging between 2.36 and 4.98 days. To assess the environmental safety of these entomopathogenic fungal strains, the best performing strains (*M. anisopliae* T331, *Metarhizium* sp. T34, *B. bassiana* A211, A214a, A214b) were applied *in vitro* to adult individuals of *Apis mellifera*. Bees were treated with gradient concentrations through trophic and topical routes, corresponding to chronic and acute intoxication. *Metarhizium anisopliae* T331 demonstrated the highest mortality in both applications, with a LT50 of 2.78 days and a mean lethal concentration (CL50) at 8.3×10^4 CFU/mL for the topical route. *Metarhizium* sp. T34 strain caused significant mortality in both applications, particularly at 10^6 CFU/mL and 10^7 CFU/mL, with LT50 and CL50 for the topical route at 5.37 days and 1.55×10^6 CFU/mL. *B. bassiana* A211 strain induced significant mortality only at a concentration of 10^7 CFU/mL, with a topical LT50 and CL50 of 7.8 days and 2.3×10^6 CFU/mL. Finally, *B. bassiana* A214a and A214b strains did not cause any significant mortality even at the highest concentration for both topical and trophic applications. The results obtained in this study offer promising perspectives for the sustainable management of the fall armyworm and field tests are currently underway on maize in Côte d'Ivoire.

Key words. *Beauveria bassiana*, biocontrol, Côte d'Ivoire, entomopathogenic fungi, *Metarhizium anisopliae*, *Metarhizium* sp., *Spodoptera frugiperda*.

The most important phytoparasitic nematodes in Zeta valley greenhouses, Montenegro

Igor Pajović

Biotechnical Faculty, University of Montenegro, Mihaila Lalića 15, Podgorica, Montenegro
e-mail address: pajovicb.igor@gmail.com

Abstract. Zeta valley is the most important part of Montenegro in the sense of greenhouses production. Nematological survey was done in 18 greenhouses permanently from 06/2006 – 12/2007. Sampling has been done by T samplers and extraction by Oostenbrinc modification of Coob method, and at end Baerman funnels. *Meloidogyne* females determination has been done by PhastSystem electrophoresis.

Following pest nematodes were detected: *Gracilacus* spp. Raski, 1962; *Pratylenchus neglectus* (Rensch, 1924) Filipjev & Schuurmans Stekhoven, 1941; *Rotylenchus macrodoratus* Dasgupta, Raski & Sher, 1968; *Helicotylenchus pseudorobustus* (Steiner, 1914) Golden, 1956, *H. platyurus* Perry, 1959, *H. vulgaris* Yuen, 1964; *Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, 1949, *M. javanica* (Treub, 1885) Chitwood, 1949, *M. arenaria* (Neal, 1889) Chitwood, 1949, *M. hapla* Chitwood, 1949, *M. ardenensis* Santos, 1968 and *Aphelenchoides* spp. Fischer, 1894. All results indicate that the most important nematode pests in greenhouses, in the area, are *Meloidogyne*. They are attacking, actually, all and any growing cultivar. Devastating damage was noticed on tomato plants, but cucumbers are the main hosts. Very sensitive are salad, Swiss chard and weeds in and near to the objects. The most tolerant, but still invaded, crop is pepper.

M. incognita has been found in 84% objects. Average relative migration coefficient (Rm) by PhastSystem for malate dehydrogenase (MDH) were 0,36 and esterase (EST) were 0,59. It has been found on cucumber, tomato, pepper, Swiss chard and salad plants; as well as on fig, gourd, *Solanum nigrum* and *Convolvulus vulgaris* near greenhouses. *M. arenaria* has been found in 25% objects; Rm was 0,33 MDH and 0,6 for EST; on *S. nigrum*, *C. vulgaris* and tomato plants. *M. hapla*, has been found in only one greenhouse; Rm was 0,56 for MDH and 0,65 for EST. *M. javanica*, Rm 0,34 MDH and 0,59 for EST, was found on gourd and pepper plants outside one object. *M. ardenensis*; Rm 0,37 for MDH and no band for EST; were found in just one object in mixed population with *M. arenaria*.

Key words. Greenhouses, nematodes, pests, *Meloidogyne* spp.

Paradigm shift in spider-mite biocontrol in Israel: Preventive application of *Neoseiulus californicus* replaces curative *Phytoseiulus persimilis* treatments in 5 cropping systems

Amit Sade, Shimon Steinberg, Amir Grossman, Yonathan Eran

Bio-Bee Sde Eliyahu Ltd., Kibbutz Sde Eliyahu, Emmek H`Maayanot, 1081000, Israel
e-mail address: *amits@biobee.com*

Abstract. The red spider mite, *Tetranychus urticae* (Acari: Tetranychidae), is one of the most devastating polyphagous pests globally, known for its rapid development of resistance to acaricides. Several biological control agents are commercially available for managing spider mites, with *Phytoseiulus persimilis* (Acari: Phytoseiidae) being the most widely used, typically as a curative measure for infestation outbreaks. Here, we report on the development and successful commercial implementation of a preventive strategy for controlling red spider mite infestations across a range of crops. The core of this approach is application of the generalist predator *Neoseiulus californicus* (Acari: Phytoseiidae) on seedlings or at the early stages of crop growth, supplemented with additional feed to support predator establishment prior to or during the onset of spider mite infestations. In field trials, the established *N. californicus* population effectively protected the crop from red spider mite damage, eliminating the need for corrective interventions with *P. persimilis* or acaricides. This preventive protocol was implemented and tested over three years in commercial cucumber, sweet pepper, watermelon, eggplant, and strawberry plots under diverse climatic conditions, greenhouses as well as open field, consistently delivering positive outcomes. As a result, it has become the leading tool for red spider mite management in the Israeli biocontrol market.

Key words. Spider mite, *Neoseiulus californicus*, preventive release.

A review of combinations of alternative pest control methods for *Phthorimaea absoluta*

Ayomidé Joseph Zannou, Jörg Romeis, Jana Collatz

Agroscope, Research Division Agroecology and Environment, Reckenholzstrasse 191, 8046 Zurich, Switzerland

e-mail address: jana.collatz@agroscope.admin.ch

Abstract. *P. absoluta* is an invasive pest causing serious damage in tomato worldwide. Long-term sustainable management cannot be achieved by the use of conventional insecticides, due to environmental impacts and emerging resistances in the pest. Alternative methods though are rarely efficient and reliable enough on their own to provide sufficient control of *P. absoluta*. We therefore reviewed the literature on available evidence for the effects of combinations of alternative pest control methods. An impressive number of 73 research articles were found detailing 174 experiments on 30 combinations of methods using 53 different control agents or substances. The most studied systems focused on combinations involving predatory mirids, *Trichogramma*-egg parasitoids and plant extracts. About 136 of the experiments reported on direct effects on agents or their attack rate on the target, while 61 reported on effects on the *P. absoluta* population or its damage, mostly under laboratory conditions. In many cases the effect was dependent on time between the application of the two agents. Field or greenhouse evidence including both agents as comparators was only given in a few cases. Here the combination of Azadirachtin and *Beauveria bassiana* as well as combination of pheromone trapping and *Bacillus thuringiensis* resulted in better control than the two methods on their own. We advocate for the implementation of field experiments when assessing combinations of alternative pest control methods, the need to include controls where the agents and substances are tested alone, as well as the inclusion of economic considerations.

Key words. *Tuta absoluta*, IPM, tomato, compatibility.

Host plant characteristics determine the success of natural enemies against the tomato leaf miner *Phthorimaea absoluta*

Ayomide Joseph Zannou¹, Judit Arnó², Jörg Romeis¹, Jana Collatz¹

¹ *Agroscope, Research Division Agroecology and Environment, Reckenholzstrasse 191, 8046 Zurich, Switzerland*

² *IRTA, Sustainable Plant Protection, 08348 Cabrils, Catalonia, Spain*

e-mail address: ayomide.zannou@agroscope.admin.ch

Abstract. Integrating host plant resistance with natural enemies offers a promising strategy for long-lasting management of *Phthorimaea* (= *Tuta*) *absoluta* (Lepidoptera: Gelechiidae), a destructive invasive pest that poses a significant threat to tomato production globally. However, morphological resistance traits, secondary metabolites, and plant volatiles of tomato can also adversely affect natural enemies, potentially impacting the overall effectiveness of pest control. In this study, we assessed the performance of three natural enemies on six tomato genotypes with varying resistance levels to *P. absoluta*. First, we examined the performance of the egg parasitoid *Trichogramma achaeae* (Hymenoptera: Trichogrammatidae) on eggs laid by moths reared on the different tomato genotypes, either isolated or on the respective tomato genotypes. Second, we evaluated the performance of the larval parasitoid *Necremnus tuta* (Hymenoptera: Eulophidae) on tomato genotypes hosting *P. absoluta* larvae. Finally, we investigated the predatory capacity of *Macrolophus pygmaeus* (Heteroptera: Miridae) on tomatoes hosting *P. absoluta* eggs and larvae, all derived from moths reared on those genotypes, as well as the survival of *M. pygmaeus* nymphs on the different tomato genotypes, both in the presence and absence of *P. absoluta* eggs. The resistant wild tomato *S. arcanum*, exhibiting a high density of glandular trichomes, negatively affected the performance of all natural enemies. In contrast, all three natural enemies performed well on the *P. absoluta*-susceptible tomatoes, the resistant domesticated Corona F1, and the resistant wild *Solanum neorickii*, all exhibited much lower densities of glandular trichome. The implications of plant defence traits in integrated management of *P. absoluta* are discussed.

Keywords. Host plant resistance; predator; parasitoid; glandular trichomes; tri-trophic interactions; integrated pest management.

Evaluation of *Clematis flammula* (Ranunculaceae) to control *Phthorimaea absoluta* (Lepidoptera: Gelechiidae)

Lemya Bentrchia¹, Jana Collatz², Şaban Kordali³

¹ *Department of Ecology and Environment, Faculty of Nature and Life Sciences. Laboratory of Cellular and Molecular Physiotoxicology -Biomolecules. University of Moustapha Ben Boulaid Batna 2, Batna 05078, Algeria*

² *Agroscope, Research Division Agroecology and Environment, Reckenholzstrasse 191, 8046 Zurich, Switzerland*

³ *Department of Plant Protection, Fethiye Faculty of Agriculture, Muğla Sıtkı Koçman University, 48300 Fethiye, Türkiye*

e-mail addresses: lemya.bentrchia@univ-batna2.dz. jana.collatz@agroscope.admin.ch

Abstract. The attack of tomato crops by the invasive *Phthorimaea absoluta* (Meyrick, 1917), formerly known as *Tuta absoluta* (Lepidoptera: Gelechiidae), has worsened since it spread outside its endemic region. To develop a botanical insecticide six plants have been screened. Of those, *Clematis flammula* had the highest effect and was thus chosen for the further research. First, we determined in the laboratory the lethal effect of the plant extract at different concentrations: 0.5mg/ml, 0.25 mg/ml, 0.1mg/ml, 0.05 mg/ml. A total of 320 L3 larvae were subjected to the test. Lethal concentrations were determined as follows: LC₂₅: 0.017 mg/ml, LC₅₀: 0.216 mg/ml, and LC₉₀: 26.822 mg/ml. Next, the efficacy of *C. flammula* aqueous extract was evaluated under field conditions by determining the proportion of leaflet area affected by *P. absoluta* larvae. Three extract concentrations (25%, 50%, 100%) with positive and negative controls (Emma Gold insecticide + water) were applied. Finally, phenolic compounds in the extract were analyzed by high-performance liquid chromatography coupled with a diode array detector (HPLC-DAD). Five compounds were detected: (1) Caffeic acid, (2) Ferulic acid, (3) Hesperedin, (4) trans cinnamic acid, (5) Apigenin. The results support the importance of plants and their effects on *P. absoluta* under laboratory and field conditions.

Key words. Tomato crops, biological control, botanical insecticide, HPLC-DAD, phenolic compounds.

Consumption of *Tuta absoluta* eggs by *Macrolophus pygmaeus* in the presence of marigold plants

Evangelos Fytas, Sofia Dervisoglou, Dionysios Perdikis

Laboratory of Agricultural Zoology & Entomology, Department of Crop Science, School of Plant Sciences, Agricultural University of Athens, 75 Iera Odos, 11855 Athens, Greece
e-mail address: vfytas@hotmail.com

Abstract. The use of *Calendula officinalis* (marigold) in a banker plant system to support *Macrolophus pygmaeus* (*Mp*) populations has been previously reported. It is considered a valuable approach which supports the establishment of the mirid and its development. However, in banker plant systems the movement of the predator from the companion to the target plant is a critical aspect which has not been extensively studied. In the current study, experiments were conducted to evaluate whether the presence of marigold may influence selection rate of tomato by *M. pygmaeus* as affected by prey availability, too. For this reason, a tomato leaflet together with a marigold leaf with or without prey were placed in Petri dishes. In the dish, a 5th instar nymph of the predator was released and its position was recorded in 10min intervals for 2h and its prey consumption in 2h and 24h. Similar experiments were conducted in cages using a young tomato and a marigold plant. *Tuta absoluta* eggs were used as prey. In the dishes, the presence of a marigold leaf reduced the selection rate of the predator for the tomato leaflet in the absence of prey whereas its prey consumption on tomato was negatively affected by the presence of marigold leaf, 2h after the predator releasing. In cages, the presence of a marigold plant without prey interestingly didn't affect the prey consumption on the tomato plant. Therefore, further studies should be conducted to explore the role of the entire marigold plant in the establishment of *Mp* on tomato crops to better realize the potential of marigold to be effectively used to support *Mp* populations.

Key words. *Macrolophus pygmaeus*, *Tuta absoluta*, tomato plant, *Calendula officinalis*.

Biological Characteristics of the Native Parasitoid *Bracon (Habrobracon) didemie* Against *Tuta absoluta* Under Laboratory Conditions

Mahmut Mete Karaca¹, Kamil Karut¹, İsmail Döker², Cengiz Kazak²

¹ Çukurova University, Agricultural Faculty, Department of Plant Protection, Laboratory of Insect Biotechnology, Adana, Türkiye

² Çukurova University, Agricultural Faculty, Department of Plant Protection, Laboratory of Acarology, Adana, Türkiye

Abstract. The tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae), is a major pest causing economic losses in tomato production in Turkey and worldwide. Although chemical control remains the primary management method, its limitations were demonstrated. *Bracon (Habrobracon) didemie* (Hymenoptera: Braconidae) has been identified as a promising candidate for biological control of *T. absoluta*. This study investigated the biological characteristics of *B. (H.) didemie* under controlled laboratory conditions (25±1°C, 70±5% humidity, 16:8 light-dark). The preferred larval stage of *T. absoluta* for parasitism by *B. (H.) didemie* was determined using choice and no-choice experiments. In no-choice experiments, individual larval stages (1st, 2nd, 3rd, and 4th instars) were separately exposed to parasitoid females, while in choice trials, all larval stages were presented simultaneously. To determine the immature development time, female parasitoids were allowed to oviposit on 4th instar larvae for 5 hours. The development time of immature stages were subsequently monitored. In no-choice experiment, female *B. (H.) didemie* induced mortality in all larval stages of *T. absoluta*, with the rates increasing with larval stages: 7% in the 1st instar, 30.8% in the 2nd instar, 36.2% in the 3rd instar, and 37% in the 4th instar. No oviposition was recorded in the 1st instar, while the average number of eggs laid per larva increased progressively in later stages (0.26 in the 2nd, 0.8 in the 3rd, and 1.53 in the 4th instar). In choice experiments, mortality was highest in the 4th instar (31.6%), with minimal oviposition in younger stages (0.06 in the 3rd, and 0.4 in the 4th instar). The total immature development time of *B. (H.) didemie* varied with sex, with females completing development in 11.23 days and males in 10.51 days. This study highlights key aspects of *B. (H.) didemie*'s biology and its potential as a biological control agent. Further research is needed to evaluate its efficacy in laboratory and field conditions.

Key words. The tomato moth, *Bracon (Habrobracon) didemie*, parasitism, larval stages, IPM.

Frenemies in action: exploring the interactions of *Dolichogenidea gelechiidivoris* with other natural enemies of *Tuta absoluta*

Angeliki Syropoulou¹, Judit Arnó¹, Pablo Urbaneja-Bernat^{1,2}

¹ IRTA, Sustainable Plant Protection, 08348 Cabrils, Catalonia, Spain

² Plant Immunity and Biochemistry Group, Department of Biology Biochemistry and Natural Sciences, Universitat Jaume I, Castelló de la Plana, Spain

Abstract. *Tuta absoluta* is a major pest threatening tomato crops worldwide. Biological control remains the primary tool in Integrated Pest Management (IPM) strategies to manage this pest. In the Mediterranean basin, successful biological control relies on zoophytophagous predators, such as *Nesidiocoris tenuis* and *Macrolophus pygmaeus*. These generalist predators primarily feed on eggs, and their larval predation rates are low. Additionally, *N. tenuis* may cause plant damage during prolonged prey shortages. Larval parasitoids, such as *Necremnus tutae*, are widely distributed in many tomato-growing regions of the Mediterranean basin. Recently, the presence of another larval parasitoid, *Dolichogenidea gelechiidivoris*, was confirmed in northeastern Spain, where it has been reported as an effective natural enemy against *T. absoluta* in the region. However, there is limited knowledge about its interactions with other natural enemies outside its native range in South America. The coexistence of these natural enemies targeting the same pest can result in diverse outcomes, including synergistic, additive, or antagonistic effects on *T. absoluta* populations. Previous studies have demonstrated that combining these parasitoids with *N. tenuis* results in synergistic benefits for controlling *T. absoluta*. However, the interactions between *D. gelechiidivoris* and both *N. tutae* and *M. pygmaeus* remain unexplored. Our ongoing research aims to elucidate these dynamics, exploring the potential competitive interactions between these parasitoids, and evaluating whether *M. pygmaeus* can also compete against *D. gelechiidivoris* preying on already parasitized larvae. Our results indicate that *D. gelechiidivoris* parasitism rates are reduced in the presence of *N. tutae*. Moreover, *M. pygmaeus* can feed on parasitized larvae by *D. gelechiidivoris*, thus reducing the efficacy of this parasitic wasp. These findings provide valuable knowledge into the interactions between these biological control agents and *D. gelechiidivoris*, underscoring the importance of understanding these dynamics to design effective IPM strategies.

Key words. Competitive interactions, predator-parasitoid interactions, *Macrolophus pygmaeus*, *Necremnus tutae*, *Dolichogenidea gelechiidivoris*.

Modulating trophic interactions among natural enemies of *Tuta absoluta* in tomato crops using artificial sugary diets

Pablo Urbaneja-Bernat^{1,2}, Angeliki Syropoulou¹, Marc Vila-Sala¹, Jordi Riudavets¹, Judit Arnó¹

¹ IRTA, Sustainable Plant Protection Program, 08348 Cabrils, Catalonia, Spain

² Plant Immunity and Biochemistry Group, Department of Biology Biochemistry and Natural Sciences, Universitat Jaume I, Castelló de la Plana, Spain

Abstract. The tomato leafminer *Tuta absoluta* is a major pest threatening tomato crops worldwide. In the Mediterranean basin, biological control efforts rely on polyphagous mirid predators such as *Macrolophus pygmaeus* and *Nesidiocoris tenuis*, which effectively target *T. absoluta* eggs but not larvae. In Catalonia, field surveys have revealed the eulophid *Necremnus tutae* and the braconid *Dolichogenidea gelechiidivoris* as dominant larval parasitoids. Preserving these parasitoids is essential for improving pest suppression. Although no competitive interactions have been reported between *N. tutae* and mirids, or between *D. gelechiidivoris* and *N. tenuis*, interactions between *D. gelechiidivoris* and *M. pygmaeus* remain poorly understood. This study explores how artificial sugary diets modulate trophic interactions between *D. gelechiidivoris* and *M. pygmaeus*, and their role in mitigating damage caused by *N. tenuis*. Our results show that *M. pygmaeus* exhibits significant intraguild predation on *T. absoluta* larvae parasitized for 72 hours by *D. gelechiidivoris*. However, providing artificial sugar significantly reduced this predation, leading to higher parasitoid emergence. Furthermore, high concentrations of sugar selectively suppressed *N. tenuis* populations without negatively affecting *M. pygmaeus*, resulting in lower plant damage. These findings demonstrate that artificial sugary diets can effectively modulate trophic interactions among natural enemies and enhance biological control in tomato crops.

Key words. *Dolichogenidea gelechiidivoris*, *Macrolophus pygmaeus*, *Nesidiocoris tenuis*, Intraguild predation.

Control of *Phthorimaea absoluta* Meyrick through a translaminar endophytic strain of *Metarhizium brunneum* Petch with systemic effect

Esther Aguilera Cuenca, María José García del Rosal, Enrique Quesada-Moraga, Meelad Yousef-Yousef*

Department of Agronomy, Unit of Excellence María de Maeztu DAUCO, ETSIAM, University of Cordoba, Cordoba, Spain

*e-mail address: z12yonam@uco.es

Abstract. The endophytic behavior of the *Metarhizium brunneum* Petch strain EAMa 01/58-Su, an entomopathogenic ascomycete (EA), offers potential for developing diverse strategic, preventive, and curative approaches to control *Phthorimaea absoluta* Meyrick (Lepidoptera: Gelechiidae), a major pest of tomatoes and the focus of this research. To evaluate the preventive strategy, the strain EAMa 01/58-Su was applied to the two basal leaves of the plant before larval infestation. The infestation involved L₂ larvae placed on untreated distant leaves at 2, 7, and 14 days post-inoculation. Larval development to the adult stage was subsequently monitored. The fungal treatment led to a 31.3% mortality rate among larvae on distant leaves, suggesting systemic activity of unknown origin, potentially linked to the induction of systemic resistance in the plant triggered by the fungal application. Furthermore, a targeted curative strategy was employed for both eggs-L₁ larvae (on the leaf surface) and L₂ larvae. For eggs-L₁ larvae, plants were exposed to adults for one day to allow oviposition. For L₂ larvae, plants were infested for one day to ensure larval establishment in plant tissues before applying the fungal suspension. This curative treatment achieved a substantial reduction of 78–90% in the preimaginal population. Evidence of infection in the cadavers further confirmed the translaminar activity of this strain, as verified by molecular techniques. These results underscore the importance of this fungus as a multifunctional agent for integration into the integrated management of *P. absoluta* in tomatoes, especially considering the expected coexistence of systemic and translaminar actions within a heterogeneous pest population and its positive effects on crop growth.

Key words. Tomato leafminer, biological control, entomopathogenic fungi, IPM, sustainability.

Evaluation of various predators for controlling the aphid *Aphis nerii* on ornamental *Mandevilla* plants

Alberto Pozzebon, Tiziano Valentini, Joaquin Castanier, Giacomo Santoiemma, Paola Tirello

University of Padova - Department of Agronomy, Food, Natural Resources, Animals and Environment (DAFNAE), Viale dell'Università 16, 35020 Padova, Italy

e-mail address: alberto.pozzebon@unipd.it

Abstract. The oleander aphid *Aphis nerii* (Boyer de Fonscolombe) is a major pest of *Mandevilla*, a market-expanding ornamental crop belonging to the milkweed Apocynaceae family. As a specialized pest on some milkweed plants, *A. nerii* can sequester plant toxic compounds (cardenolides) and exploit them as defence mechanisms against natural enemies, making the development of biological control strategies particularly challenging. This study evaluates the suitability of *A. nerii* as prey for seven generalist predators, as well as their ability to suppress the aphid population. Tested predators were: *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae), *Sphaerophoria rueppellii* Wiedmann (Diptera: Syrphidae), *Episyrphus balteatus* DeGeer (Diptera: Syrphidae), *Micromus angulatus* Stephens (Neuroptera: Hemerobidae), *Propylea quatuordecimpunctata* L. (Coleoptera: Coccinellidae), *Adalia bipunctata* L. (Coleoptera: Coccinellidae), and *Sympherobius fallax* Navas (Neuroptera: Hemerobidae). Then, we assessed the predation rates and the functional response of *C. carnea*, *M. angulatus*, and *P. quatuordecimpunctata* preying on *A. nerii*. Results showed that *M. angulatus*, *P. quatuordecimpunctata*, and *S. rueppellii* can survive, develop, and reproduce on *A. nerii*, while this aphid was unsuitable prey for the other predators. *Chrysoperla carnea* did not show a response to varying densities of *A. nerii*; in contrast, both *M. angulatus* and *P. quatuordecimpunctata* exhibited a Type II functional response highlighting their potential for *A. nerii* control.

Key words. *Aphis nerii*, *Mandevilla*, augmentative biological control, generalist predator, functional response.

Tandem use of endophytic entomopathogenic fungi and the generalist predator *Chrysoperla carnea* for reduced-risk aphid management

María Cuenca-Medina, Natalia González-Mas, Óscar Martínez-Anguila, Andrés Sandoval-Lozano, Enrique Quesada-Moraga

Department of Agronomy, Maria de Maeztu Excellence Unit DAUCO, ETSIAM, University of Cordoba, Campus Universitario de Rabanales, 14071 Cordoba, Spain

Abstract. The melon aphid *Aphis gossypii* is one of the most economically important crop pests that can be presently managed at greenhouse conditions with different commercial mycoinsecticides. Recent studies also highlight the systemic efficacy of entomopathogenic endophytic ascomycetes (EA) targeting aphids through the plant, therefore preventing possible risks related to the contact between the fungal inoculum and beneficial insects, whereas the compatibility of such strategy with natural enemies has not yet been explored. In this study, we evaluated the biocontrol potential of two endophytic EA strains against *A. gossypii* in melon crops under greenhouse conditions. Based on their known endophytic behaviour, *Metarhizium brunneum* EAMa 01/58-Su and *Beauveria bassiana* EABb 01/33-Su strains were applied as a foliar spray and seed dressing respectively. Furthermore, the compatibility of these EA applications with the predator *Chrysoperla carnea* was assessed in a greenhouse in Córdoba (Spain), both in summer and in autumn. It is noteworthy that, in summer, foliar spraying with *M. brunneum* resulted in 35.0% aphid mortality and a 20.4% reduction in total per capita nymph production (TCNP) on sprayed colonised leaves. In contrast, leaves not sprayed with the fungal suspension but endophytically colonized caused 70.0% aphid mortality and a 12.6% reduction in TCNP, which demonstrates the systemic potential of this fungus. Compatibility between *C. carnea* and *M. brunneum* was also demonstrated, with a significant increase in prey consumption on endophytically-colonized leaves as compared with the controls. Seed dressing with *B. bassiana* led to 55.0% aphid mortality and a 19.2% reduction in TCNP but had no significant effect on *C. carnea* predation. The same trends were observed in autumn, although colder temperatures reduced aphid mortality. Our results highlight the potential of fungus-predator biocontrol strategies within an aphid Integrated Pest Management programme under greenhouse conditions.

Key words. *Aphis gossypii*, *Beauveria bassiana*, *Metarhizium brunneum*, endophyte, compatibility, greenhouse.

Is there a link between protective endosymbionts, genotypes and parasitoids of the potato aphid (*Macrosiphum euphorbiae*) on strawberry crops?

Laura M. Martinez-Chavez¹, Alison J. Karley², Francis Wamonje³, Joe Roberts¹, Tom W. Pope¹

¹ Harper Adams University, Newport, Shropshire, TF10 8NB, UK

² The James Hutton Institute, Invergowrie, Dundee, DD2 5DA, UK

³ NIAB, East Malling, West Malling, Kent, ME19 6BJ, UK

Abstract The potato aphid (*Macrosiphum euphorbiae*) is an economically important pest of strawberry crops for which the current management relies on biological control with parasitoid wasps. The recent description of resistance to this parasitic wasp in some populations of *M. euphorbiae* could indicate a reduction in the effectiveness of its biological control. Resistance of aphids to parasitoids has been linked to aphid genotype and endosymbiotic infections, but most of the research on this topic have been done under laboratory conditions, which oversimplifies the complexity of the factors involved in the interaction. Here, we aim to test under field conditions whether the endosymbiont communities or genotypes of *M. euphorbiae* have a protective effect on their hosts and whether their diversity in the field are linked to parasitoid community diversity. To achieve this, we monitored systematically four open polytunnels in a strawberry farm from March to November 2023. We found a high diversity of aphid genotypes over the season, with five of them present throughout it. Single and multiple secondary bacteria were found with a noticeable increase in the frequency of infection with *Regiella insecticola* at the end of the season. The parasitoid community was dominated by *Aphidius ervi* and *Praon volucre*. Data analysis showed an interaction between the more abundant genotypes and parasitism pressure, showing that potato aphid parasitism is linked to its genotype and not secondary endosymbiont infections. No correlation between diversity indexes were found between potato aphid genotypes, secondary endosymbionts, and parasitoid communities, showing that a fluctuation in the intraspecific diversity of potato aphids does not translate into a fluctuation in the diversity of their main natural enemies. Together, this information informs on the likely effect of endosymbionts and genotypes on the effectiveness of biological control programmes based on parasitic wasps for control of *M. euphorbiae* in strawberry crops.

Key words. *M. euphorbiae*, genotypes, endosymbionts, parasitism, resistance, field.

A *Beauveria bassiana* Balsamo Vuill. strain for *Macrosiphum euphorbiae* (Thomas) control and plant growth promotion in tomato

María Cuenca-Medina¹, Ioannis-Konstantinos Platis^{1,2}, Enrique Quesada-Moraga¹, Natalia González-Mas¹

¹ *Department of Agronomy, ETSIAM, University of Cordoba, Campus Universitario Rabanales, Cordoba, ES*

² *Laboratory of Plant Health Management, Department of Agrotechnology, University of Thessaly, Geopolis, 41500 Larissa, Greece*

e-mail address: z22goman@uco.es

Abstract. Entomopathogenic ascomycetes have been successfully employed as endophytes for systemic plant protection. These fungi have demonstrated to protect several crops against insect pests, plant pathogens, and abiotic stresses. In this study, an endophytic strain of *Beauveria bassiana* (EABb 01/33-Su) was applied to tomato plants to protect them from the aphid *Macrosiphum euphorbiae*.

Three application methods (foliar spray, soil application, and seed dressing) were evaluated to determine the most effective approach for achieving high colonization rates. Based on the results, foliar spray emerged as the optimal method for applying the *B. bassiana* strain. Additionally, fungal suspensions with concentrations of 10^4 , 10^6 , and 10^8 conidia/mL were tested to identify the concentration that maximized plant colonization while minimizing fungal product. While 10^8 conidia/mL achieved the highest colonization rate in target leaves (52.0%), no significant differences were observed between 10^6 , and 10^8 conidia/mL in the colonization of non-target leaf tissues (2.0%).

The impact of *B. bassiana* endophytic colonization on *M. euphorbiae* was assessed by measuring aphid mortality and fecundity over one week of exposure to colonized tomato plants. The treatment resulted in aphid mortalities of 88.75% on target leaves and 78.85% on distant leaves. Furthermore, total fecundity was reduced by 36.0% and 24.0% on target and distant leaves, respectively. These findings highlight the potential of *B. bassiana* endophytic treatments for effective control of *M. euphorbiae* populations.

Finally, it was observed that endophytic colonization enhanced plant growth parameters, including root length and chlorophyll content, which are critical for improving overall crop production.

Key words. Entomopathogenic fungi, aphids, horticultural crop.

Multi-target gene silencing via nanoparticle-delivered dsRNA: an efficient approach for *Myzus persicae* management

Rusul Abdulridha Alghadab^{1,2}, Leonardo Velasco¹

¹ Instituto Andaluz de Investigación y Formación Agraria (IFAPA), 29140 Churriana, Málaga, Spain

² Universidad de Málaga, Málaga, Spain

e-mail address: leonardo.velasco@juntadeandalucia.es

Abstract. The green peach aphid (*Myzus persicae*) represents a challenging agricultural pest, capable to harm crops through direct feeding damage and vectoring over 100 plant viruses. While RNA interference (RNAi) offers a promising species-specific control strategy, its application has been hindered by dsRNA inefficient plant and insect uptake. This study systematically evaluates carbon dot (CD) and chitosan-tripolyphosphate (ChNP) nanoparticles as delivery vehicles for simultaneously dsRNA targeting of five essential aphid genes (acetylcholinesterase-like, nicotinic acetylcholine receptor, carboxylesterase, cytochrome P450 and Ya1 lncRNA). We found that nanoparticle complexation enhanced dsRNA retention on pepper leaves by 17.2–23.4-fold compared to naked dsRNA ($P < 0.05$). Two methods of delivering dsRNAs, either complexed with NPs or as naked molecules, were used and compared to control given by a conventional synthetic insecticide: direct application on the aphids at lower pressure or spraying on leaves at 2 bars and letting the insects fed them. Results revealed a reduced target transcript levels by 68–84% in the treated aphids, culminating in 89% mortality (dsRNA:CD) and suppression of progeny production effects mirroring those of spirotetramat (85.5% mortality) at 144 h. In a subsequent greenhouse experiment, pepper plants were treated with either the mentioned insecticide, dsRNA:NPs, or left untreated, then challenged starting with 20 aphids per plant. After 4 weeks reaching full infestation in anti-thrips cages, plants treated with dsRNA:ChNP exhibited significantly greater aerial biomass compared to untreated controls ($P < 0.001$) and spirotetramat-treated plants ($P = 0.006$). While dsRNA:CD-treated plants showed comparable aerial mass to insecticide-treated ones, the latter displayed reduced photosynthetic efficiency ($P < 0.05$) and partial defoliation. These findings provide compelling evidence for nanocarrier-mediated RNAi as an effective and environmentally favourable aphid control strategy.

Key words. Green peach aphid, control, RNAi, dsRNA, carbon dots, chitosan nanoparticles.

The role of spiders as biological control agents in greenhouse crops - preliminary study

Ada Leman, Kyra Vervoorn, Marcel Heijkoop, Nathan Koedijk, Denise Sewkaransing, Khanh Pham, Sophie Le Hesran

Wageningen University and Research, Business Unit Greenhouse Horticulture and Flower Bulbs, Violierenweg 1, 2665 ZG Bleiswijk, The Netherlands

e-mail address: ada.leman@wur.nl

Abstract. In recent years, more attention has been paid to generalist predators in biological pest control of greenhouse crops due to their potential to target a wide range of pest species that persist year-round. This shift is supported by the increased availability of supplementary food sources. Among generalist predators, spiders are well-known for their predatory capabilities, however their role in pest management remains understudied.

In our research, we evaluated the potential of three Linyphiidae spider species in pest control: the dwarf spider *Erigone dentosa* O. Pickard - Cambridge, the sheetweb spider *Ostearius melanopygius* (O. Pickard-Cambridge), and the sheet weaver spider *Mermessus denticulatus* (Banks). All spider predators were preventively introduced into ornamental crops and supplemented with additional food if necessary. The pest targeted were *Lyprauta cambria* (Diptera: Keroplatidae), *Thrips parvispinus* (Thysanoptera: Thripidae) and *Empoasca decipiens* (Hemiptera: Cicadellidae) in Phalaenopsis, Anthurium and Amaryllis, respectively. All three pests remain unresolved problems for these crops, causing economic damage and increasing pesticide use.

The pest suppressive effects of spiders were assessed through pest population dynamics. Spider gut-content analysis was performed to confirm predation. In the experiment, a spontaneously-appearing Theridiidae spider predated on *L. cambria*. The introduced spiders consumed *E. decipiens* in the experiment, leading to reduction in pest populations compared to the control treatment.

This study provides preliminary insights into the potential of spiders as biological control agents in greenhouse crops, opening the way for further research into their efficacy and integration into pest management strategies.

Key words. Spiders, generalist predators, biological control, ornamentals.

Plant damage by mirids - are there differences between species?

Elisabete Figueiredo^{1,2}, Gonçalo Abraços-Duarte^{1,2}, Paula Souto³, Rita Morais¹, Generosa Teixeira⁴

¹ Instituto Superior de Agronomia, Universidade de Lisboa. Tapada da Ajuda, 1349-017 Lisboa, Portugal, (R. Morais' present affiliation: InnovPlant Protect, Apartado 72, 7351-901 Elvas; G. Abraços-Duarte' present affiliation: Koppert Portugal, Alcoffice Centro de Escritórios, 2890-042 Alcochete)

² LEAF - Linking Landscape, Environment, Agriculture and Food, Associate Laboratory TERRA, Tapada da Ajuda, 1349-017 Lisboa, Portugal

³ Centre for Functional Ecology – Science for People & the Planet (CFE), Department of Life Sciences, Associate Laboratory TERRA, University of Coimbra, Coimbra, Portugal

⁴ CHANGE - Global Change and Sustainability Institute, Ce3C - Centre for Ecology, Evolution and Environmental Changes, Fac. Farmácia, Universidade de Lisboa, Portugal

e-mail address: elisalacerda@isa.ulisboa.pt

Abstract. Three dicyphine mirids are common in Portuguese greenhouses: *Dicyphus cerastii*, *Nesidiocoris tenuis* and *Macrolophus pygmaeus*, the first two being dominant. Their damage to plants varies in appearance and economic importance. Within the TomBugBite and ASTER projects, we used histological and observational data to: (1) compare the histological damage caused by *Nesidiocoris tenuis* and *Dicyphus cerastii*; (2) compare the behaviour of *D. cerastii* and *N. tenuis* females on tomato plants; (3) assess whether the feeding and probing behaviour of *D. cerastii* and *N. tenuis* females changes when exposed to plants previously infested by *N. tenuis* or *D. cerastii* compared to a healthy plant; and (4) determine whether females of either species prefer to feed on damaged or healthy plants. For morpho-anatomical observations, insect-damaged plant organs were collected from tomato plants and examined under fluorescence and scanning electron microscopy. For behavioural tests, starved females were placed at the bottom of a cylindrical box containing a plant (healthy or damaged by mirids), and feeding, probing, foraging, walking, oviposition, out-of-plant and out-of-sight behaviours were recorded for 30 min. Damage caused by *N. tenuis* was brownish and reached the phloem, xylem and parenchyma, whereas caused by *D. cerastii* was grey and did not reach the parenchyma. *N. tenuis* and *D. cerastii* did not differ in time spent feeding; however, *N. tenuis* probed the plant significantly more than *D. cerastii*. Both species probed more and spent more time feeding on healthy than on attacked plants (no difference between conspecific and heterospecific attacked plants).

Key words. *Dicyphus cerastii*, *Nesidiocoris tenuis*, generalist predator, histology, behaviour, zoophytophagy.

Current status and future prospects of biological control using the zoophytophagous mirid bug *Nesidiocoris tenuis* in Japan

Norihide Hinomoto¹, Junichiro Abe², Ryohei Nakano³, Takuya Uehara⁴

¹ Laboratory of Ecological Information, Graduate School of Agriculture, Kyoto University, Kyoto 606-8502, Japan;

² Institute for Plant Protection, National Agricultural Research Organization (NARO), Tsukuba, Ibaraki 305-8666, Japan;

³ Shizuoka Prefectural Research Institute of Agriculture and Forestry, Iwata, Shizuoka 438-0803, Japan;

⁴ Institute of Agrobiological Sciences, National Agricultural Research Organization (NARO), Tsukuba, Ibaraki 305-8634, Japan;

e-mail address: hinomoto.norihide.8m@kyoto-u.ac.jp

Abstract. The zoophytophagous mirid bug *Nesidiocoris tenuis* is now widely used for biological control of minute insect pests such as whiteflies and thrips in Japanese protected horticulture, especially on eggplants, cucumbers and tomatoes. In southern parts of Japan, where indigenous populations of *N. tenuis* are distributed in the field, they are collected using secondary plants such as sesame, *Sesamum indicum*, and spider flowers, *Cleome hassleriana*, and released in commercial greenhouses. In northern parts, where they can be rarely found in the field, commercially available strains are used against whiteflies on tomatoes and thrips on cucumbers. However, their longer generation period relative to their prey species requires longer period to increase their population when pests are scarce, even though biological control agents should be released at low pest density in the theory. In such situations, banker plants such as vervain, *Verbena x hybrida*, and fairy fan-flower, *Scaevola aemula*, in addition to sesame and spider flowers are planted in greenhouses. Tracking their movements by using molecular markers proved that they effectively move around in these banker plants and crops. However, when they stucked on banker plants, violet LED light can be used to enhance their withdrawal from banker plants. Last problem is their phytophagy. It is well-known that necrotic rings appear on tomato plants when their density became extremely high. To reduce them, genomic breeding is now conducted based on high-quality genome data.

Key words. *Nesidiocoris tenuis*, secondary plants, banker plants, violet LED, molecular analysis.

Elucidating the role of *Nesidiocoris tenuis* in Italy: a contemporary perspective

Gaetano Siscaro, Michele Ricupero, Antonio Biondi, Antonio Gugliuzzo, Giovanna Tropea Garzia, Lucia Zappalà

Department of Agriculture, Food and Environment, University of Catania, 95123 Catania, Italy

Abstract. *Nesidiocoris tenuis* (Reuter) (Hemiptera: Miridae) is a valuable generalist predator of several key pests in Mediterranean protected crops. However, its actual role in crop protection has been questioned for decades. Upon the first introduction of *Tuta absoluta* in Italy, few natural enemy species were identified as potential biological control agents, and *N. tenuis* has rapidly gained importance due to its high efficacy against the new pest. In this scenario, various studies have been carried out with the aim to evaluate new sustainable strategies exploiting the role of this predator, while managing its potential negative impacts own to its herbivory. Biotic interactions influencing *N. tenuis* populations in Italian tomato crops have been studied with reference to the model of the invasive pest *T. absoluta*. The zoo-phytophagous mirid has been extensively investigated for its pest biocontrol services and its ability to induce direct and indirect plant defenses in tomato. Our studies showed the ecological success of *N. tenuis* over indigenous parasitoids by competitive interactions. A multi-prey system trials combining *N. tenuis* and *Macrolophus pygmaeus* in presence of *Bemisia tabaci* and *T. absoluta* demonstrated that using both mirid predators together reduces *N. tenuis* density, maintains biocontrol efficiency reducing plant feeding activity. Augmentative and conservation biological control strategies based on *N. tenuis* have proven effective in managing *T. absoluta*. Sesame and verbena have been evaluated, as companion plants to mitigate tomato damage caused by *N. tenuis*, with promising results. The toxicity of synthetic and naturally derived pesticides currently used in various protected crops was tested for the compatibility with *N. tenuis*. Sustainable control tools and new attractive compounds were also identified to incorporate the mirid into IPM programmes. Continued research and implementation efforts are crucial to promote the use of this effective biocontrol agent in Italy.

Keywords. Omnivorous mirid; ecotoxicology; conservation biocontrol; IPM; population dynamics.

Diurnal patterns and impact of temperature on activity of *Nesidiocoris tenuis*

Yui Tamada, Norihide Hinomoto

Laboratory of Ecological Information, Graduate School of Agriculture, Kyoto university, Kyoto, Japan

e-mail address: *hinomoto.norihide.8m@kyoto-u.ac.jp*

Abstract. The zoophytophagous mirid bug *Nesidiocoris tenuis* (Reuter) (Hemiptera: Miridae), which is widely distributed around the world, is used as a biological control agent against insect pests such as whiteflies and thrips. In order to improve the effectiveness of biological control by this species, the ecology of the species in diverse field environments needs to be further elucidated. Although the long-term seasonal variation in emergence of *N. tenuis* has been investigated in various fields around the world, there are no reports on the activity time or diurnal activity in periods of time shorter than a day. To enhance their activity and/or effectiveness as a biocontrol agent, the use of HIPVs or purple light has been proposed as a method to control the behaviour of *N. tenuis*. However, if their activity depends on factors such as time and temperature, the effects of these methods cannot be properly assessed. In this study, we investigated the amount of their daily activity by using the locomotor activity monitor (LAM10, TriKinetics Inc., MA, USA). The results showed that the activity was higher during the dark period and showed a daily cycle. The behaviour was most active at 25°C, and the activity was significantly lower at lower temperatures. In summary, *N. tenuis* is active at night, and they are less active at low temperatures. These results suggest that nighttime heating in the greenhouses will be important for their full potential as a biocontrol agent.

Key words. *Nesidiocoris tenuis*, diurnal rhythm, diel activity, temperature.

Behavioural responses of the zoophytophagous predator *Nesidiocoris tenuis* (Reuter) to melon and tomato plants endophytically colonized by the entomopathogenic fungus *Beauveria bassiana* (Balsamo) Vuillemin

Natalia González-Mas¹, María Cuenca-Medina¹, Antonio Ayllón-González¹, José Manuel Muñoz-Redondo², José Manuel Moreno-Rojas², Enrique Quesada-Moraga¹

¹*Department of Agronomy, ETSIAM, University of Cordoba, Campus Universitario Rabanales, Cordoba, Spain*

²*Department of Food Science and Health, Andalusian Institute of Agricultural and Fisheries Research and Training (IFAPA), Alameda del Obispo, Avenida Menéndez Pidal, S/N, 14004 Cordoba, Spain*

e-mail address: z22goman@uco.es

Abstract. Entomopathogenic fungi (EF) like *Beauveria bassiana* are effective biological control agents that not only act by direct contact but also provide systemic protection to plants from insect pests. Through endophytic colonization, these fungi enhance compatibility with natural predators by reducing direct contact with them. However, the impact of such colonization on zoophytophagous predators, which feed on both prey consuming EF-colonized plants and the plants themselves, is not well understood. This study investigated the effects of systemic protection in melon and tomato plants by *B. bassiana* on the behavior of the zoophytophagous predator *Nesidiocoris tenuis*, in both infested and non-infested conditions with *Bemisia tabaci* nymphs.

The results revealed that *N. tenuis* preferred *B. bassiana*-colonized tomato plants when no prey were present. However, when tomato plants were infested by *B. tabaci*, the predator initially chose EF-colonized plants for the first two hours, then moved to control plants. In contrast, no preference was observed for *B. bassiana*-colonized versus control melon plants, regardless of whether the plants were infested. This may be due to *N. tenuis* being more sensitive to volatile compounds from tomato plants than melon plants.

Volatile profile analysis showed significant variations between treatments, with higher concentrations of the green leaf volatile (z)-3-hexen-1-ol, an attractant for *N. tenuis*, in *B. bassiana*-colonized plants. These findings suggest the potential for *B. bassiana* to attract *N. tenuis*, warranting further investigation under greenhouse and field conditions.

Key words. *Bemisia tabaci*, natural enemies, endophyte; volatiles; multitrophic interactions; biological control.

***Orius* predators and *Diglyphus isaea*: A matching pair for the control of leaf miners in chrysanthemum**

Angelos Mouratidis^{1,2}, Ada Leman¹, Amador Rodríguez-Gómez³, Gerben J. Messelink^{1,4}

¹ *BU Greenhouse Horticulture & Flower Bulbs, Wageningen University & Research, Bleiswijk, the Netherlands*

² *Departamento de Protección Vegetal, Instituto Canario de Investigaciones Agrarias (ICIA), La Laguna, Tenerife, Spain*

³ *Departamento de Ingeniería Agronómica, Universidad Politécnica de Cartagena, Cartagena, Spain*

⁴ *Laboratory of Entomology, Wageningen University & Research, Wageningen, the Netherlands*

e-mail address: *angelos.mouratidis@outlook.com*

Abstract. Leaf miners (Diptera: Agromyzidae) are important polyphagous pests, that cause damage to many horticultural crops. Parasitoids, such as *Diglyphus isaeae* (Hymenoptera: Eulophidae), are commercially available for leaf miner control, but additional pesticide applications are often necessary. In many ornamental crops where leaf miners are problematic, *Orius* (Hemiptera: Anthocoridae) predators are frequently used, predominantly for the control of thrips. These omnivorous predators are known to feed on various arthropods, including aphids and whiteflies, however predation on leaf miners has not been previously evaluated.

This study evaluated the suppressive effects of *Orius laevigatus* and *O. majusculus* on *Liriomyza trifolii* in cut chrysanthemum, a crop frequently attacked by this pest. Their efficacy was compared to *D. isaeae* in a greenhouse cage trial. Predators were released preventively and supported with *Artemia* cysts before infestation with leaf miner adults. Parasitoids were released a week later, when suitable leaf miner larvae were present.

Both *Orius* predators significantly reduced the number of mines, achieving suppression comparable to *D. isaeae* by the end of the cropping cycle. The least damage occurred in treatments combining *Orius* and *D. isaeae*, indicating limited negative interactions such as intraguild predation between these natural enemies. Laboratory observations further revealed that *Orius* predators can feed on recently formed pupae before sclerotization, but predation of larvae within the mines was only rarely observed.

Our results suggest that a well-established population of *Orius* predators in the crop may have an important role in suppressing leaf miners, complementary to that of specialist parasitoids.

Key words. Parasitoid, Anthocoridae, predator-in first.

Make way for the young too

Helmi Leino^{1,3}, Jacopo Menghi², Jan Hulshof³

¹ *University of Helsinki, Fac. of Agriculture and Forestry, Dept. of Agricultural Sciences*

² *CBC Bioplanet, via Maccanone 359, Cesena 47522, Italy*

³ *Biotus Oy, Tiilenlyöjankatu 5, 30100 Forssa, Finland*

Abstract. The increasing need to find alternative solutions for the biological control of both emerging and established pest species presents growing challenges for sustainable agriculture. While biological control remains a key component of Integrated Pest Management (IPM), the availability of effective natural enemies is often limited by regulatory constraints, production challenges, and delayed accessibility. Historically, commercially available species have been marketed in few specific life stages; however, expanding the use of alternative developmental stages could offer new tools for biological control applications. Life stages' diversification could offer unique advantages in different crop conditions and environments, allowing the improvement of pest control in new or challenging conditions.

In response to these challenges, an innovative approach focused on previously under-utilized life stages of natural enemies could be considered. Specifically, the introduction of early nymphal stage (N2) *Orius laevigatus*, a new formulation that employs young, non-flying N2 instars of this well-known predator, can represent a valid alternative to the already present on the market thrips' beneficials. Although these juveniles are highly mobile and exhibit strong predatory behaviour, their inability to fly ensures they remain within the crop, delivering consistent and localized pest control even in parts of the plant typically less accessible to traditional agents.

A practical evaluation in tunnel-produced strawberries was conducted during the 2024 growing season at Alanne Farm in Finland. Statistical analysis (ANOVA) confirmed that the treatment incorporating the early nymphal stages of *O. laevigatus* maintained thrips populations below the economic damage threshold more effectively than conventional approaches. These findings underscore the potential of integrating young developmental stages into IPM programs, offering a flexible and robust tool for sustainable pest management in modern agricultural systems.

Key words: *Orius laevigatus*; early nymphal stage; biological control; strawberry; thrips.

Side-effects of azadirachtin on the predatory bug *Orius laevigatus* under controlled conditions

Claudia Sbrighi¹, Edith Ladurner¹, Stefano Tassinari², Massimo Benuzzi¹

¹ CBC (Europe) S.r.l. - BIOGARD Division, Area Tecnica - Via Civinelli, 1090 47522 Cesena (FC), Italy

² CBC Bioplanet soc. agr. Srl - Via Maccanone 359 47522 Cesena (FC), Italy

Abstract. In 2023 and 2024, two trials were carried out on potted bell pepper plants to evaluate the side-effects of an azadirachtin-based insecticide on the predatory bug *Orius laevigatus*. In particular, the studies aimed at investigating: 1. whether a dose-response effect in the susceptibility of the beneficial insect towards the insecticide exists; 2. whether side effects vary depending on when the insecticide is applied (i.e. before or after the release of *O. laevigatus* adults). In both trials, the azadirachtin-based product was tested at half the recommended, the recommended, and twice the recommended field rate, but at different timings of application. While in 2023 the insecticide was applied 2 days before the release of *O. laevigatus* adults and consequent egg-laying on the plants, in 2024 the insecticide was applied 2 days after the release of the predator, when eggs had already been laid. Plants treated with water only acted as control. At the expected end of the egg-hatching period (approx. 2 weeks after the release of *O. laevigatus* adults), the number of living nymphs present per plant was counted, and percent reduction in nymph numbers compared to the water-treated control was determined. When the azadirachtin-based insecticide was applied before the release of *O. laevigatus* adults, a clear dose-response effect emerged, with the insecticide being harmless at half the recommended rate, slightly harmful at the recommended rate, and moderately harmful at twice the recommended rate. On the contrary, when adults were released before the insecticide spray, the reduction in nymph numbers was high and similar at all tested rates. These findings show the importance of proper timing of insecticide sprays and release of beneficials.

Key words: azadirachtin, *Orius laevigatus*, selectivity, side-effects, beneficials.

Astigmatid mites as supplementary food in crops for *Orius laevigatus* (Hemiptera: Anthocoridae) strains adapted to suboptimal feeding

Amador Rodríguez-Gómez, Ana Belén Abelaira, Virginia Balanza, María del Carmen Reche, Pablo Bielza

BioControl Selection Lab, Polytechnic University of Cartagena, Spain

Abstract. Integrated Pest Management (IPM) using biological control agents has proven highly effective in many crops, particularly those grown in greenhouses of the Mediterranean area. A key factor in this success is the use of omnivorous predators, which can feed on various prey and survive on alternative food sources when primary prey is scarce. *Orius laevigatus* is a prominent example of such an omnivorous predator, widely used in the Mediterranean basin and northern Europe. While it is essential for controlling different species of thrips, it can also feed on pollen, allowing for preventive releases before pest outbreaks. However, when pollen is limited, supplementary food sources are often necessary. Traditionally, *Ephestia kuehniella* eggs or *Artemia* cysts have been used, but their cost can be prohibitive. Astigmatid mites, commonly used to feed phytoseiid mites, are a more cost-effective alternative. While hemipteran predators generally don't thrive on these mites, the Biocontrol Selection Lab in Cartagena has successfully selected *O. laevigatus* strains that exhibit improved survival and fecundity when fed astigmatid mites. Comparative studies between selected and commercial *O. laevigatus* populations revealed significant differences in performance when fed on various astigmatid mite species. The selected strains displayed greater nymphal survival and fecundity, particularly when fed on *Acarus siro*. Therefore, *A. siro* emerges as a promising, cost-effective supplementary food source to enhance the establishment of selected *O. laevigatus* strains within biological control strategies.

Key words. Biological control, omnivorous predator, selective breeding, strains.

Managing the complexity of deploying microbial biocontrol agents against plant diseases in an IPM context

Marc Bardin¹, Philippe Nicot¹, Thomas Oudin¹, Marc Tchamitchian², Aurélie Rousselin³, Thomas Pressecq^{1,4}

¹ *Plant Pathology, INRAE, Montfavet, 84140, France*

² *Ecodeveloppement, INRAE, Avignon, 84000, France*

³ *APREL, Saint-Rémy-de-Provence, 13210, France*

⁴ *Syndev, Les Bois d'Anjou, 49250, France*

e-mail address: marc.bardin@inrae.fr

Abstract. The control of plant diseases using microorganisms has been the subject of intensive research over recent decades, leading to the identification of numerous beneficial microorganisms and the marketing of a growing number of microorganism-based biocontrol products. To assess whether these products are actually being used, a survey was carried out among French farmers and farm advisors. The survey revealed that biocontrol microorganisms are still poorly used against plant diseases, the main reason being that their efficacy is often considered variable and sometimes unsatisfactory.

This instability in protective efficacy may be due to their non-optimal use in the field. Indeed, numerous biotic and abiotic factors can modulate the efficacy of biocontrol agents, which can make their practical use more complex than that of chemicals. It is therefore essential to manage this complexity to optimize their application in the field, and to combine them properly with other protective tools as part of integrated pest management (IPM) strategies.

To this end, a database has been set up, bringing together all the information available in the scientific literature on the efficacy factors of biocontrol microorganisms registered in Europe against plant diseases. This database will be used to establish practical guidelines to help farmers choose the most suitable biocontrol products for specific situations, and to obtain indications on the most effective way of using them.

Keyword. Biocontrol, plant diseases, efficacy, guidelines, decision-support-tool.

Does plant genetics shape the protective efficacy of biocontrol against diseases?

Awa Sangaré^{1,2}, Jean-François Bourgeay¹, Anne Massire², Bernard Caromel², Marc Bardin¹

¹Plant Pathology, INRAE, Montfavet, 84140, France

²Genetic and breeding of fruits and vegetables, INRAE, Montfavet, 84140, France

e-mail address: awa.sangare@inrae.fr

Abstract. Over the last few decades, research on biocontrol, and particularly on natural substances that induce plant defense mechanisms, known as Plant Resistance Inducers (PRIs), has considerably expanded. These studies have primarily focused on elucidating their modes of action and identifying factors that influence their efficacy under controlled and field conditions. Several investigations have demonstrated variations in PRI efficacy depending on plant genotypes. However, few studies have explored the genetic basis of plant responses to PRIs. In our research, we investigated the role of genetic variation in determining the protective efficacy of PRIs against plant pathogens. To achieve this, we focused on two major pathogens of tomato plants: *Oidium neolycopersici* and *Phytophthora infestans*. First, we conducted a transcriptomic analysis to study the genetic variation in the induction of defense-related genes by four natural substances across five tomato accessions with similar susceptibility levels. Next, we examined the effect of tomato genetic variation on PRI efficacy. This effect was quantified using heritability estimates for both pathogens. Our findings reveal that, for both pathogens, over 50% of the phenotypic variation in PRI efficacy can be attributed to genetic variation within the tested accessions.

Future research will aim to identify the genomic regions involved in the observed variation in plant responses to PRIs for each pathogen. These insights will provide valuable tools for breeders, enabling the selection of new tomato varieties that respond favorably to PRIs. This approach will contribute to the sustainable improvement of biological and integrated pest management strategies in protected crop systems.

Key words. Plant resistance inducers, biocontrol, tomato, genetic effect.

Biological innovations: a new tool for biological control of Powdery Mildew

Tham Nguyen, Gerben Messelink, Johanna Bac-Molenaar

Wageningen UR Greenhouse Horticulture, PO Box 20, 2265 ZG Bleiswijk, The Netherlands
e-mail address: *tham.nguyen@wur.nl*

Abstract. Ladybird beetles (family Coccinellidae) are generally viewed as aphidophagous predators, but their diet is much more diverse and often includes hemipterans, beetles, fungi, and plant materials. Recent studies have advanced understanding of their mycophagy, which is classified as either obligate or facultative. Facultative species feed on a wide range of diets, including fungi as supplementary food, such as members of the *Tytthaspidini* tribe and aphidophagous *Coccinellini*. In contrast, obligate species rely exclusively on fungi to complete their life cycle, such as members of the *Halyzia* tribe. Species belong to *Halyzia* and *Tytthaspidini* possess some structural specialization indicating adaptation to mycophagy. Both feeding strategies hold potential for the biological control of pathogenic fungi, particularly the causal agents of powdery mildew (Erysiphales), an important disease in many greenhouse and open field crops. Therefore, my project will study native Dutch mycophagous ladybird beetles for powdery mildew (PM) control in strawberry greenhouses, focusing on four species: *Halyzia sedecimguttata* (H16), *Vibidia duodecimguttata* (V12), *Tytthaspis sedecimpunctata* (T16), and *Psyllobora vigintiduopunctata* (P22). Insect collections were conducted from April to September 2024, when PM was the most prevalent in open field. The ladybird beetles were found actively feeding on PM on various host plant species, establishing them as one of the most important PM consumers. This hold a promise for application inside greenhouse. My key objectives will include: (1) identifying essential dietary components and breeding behaviors, (2) evaluating how environmental factors, such as light and temperature, influence their development and activity, (3) assessing their capacity to consume and control PM in laboratory and greenhouse conditions, and (4) developing an early-season biocontrol strategy, incorporating a standing army and open-rearing system. By addressing knowledge gaps in the biology and biocontrol potential of these beetles, we hope to provide growers with biological tools for PM management strategies.

Keywords. Ladybird beetles, mycophagy, powdery mildew, biological control.

Assessing commercial tomato cultivars for their effects against key arthropod pests

Maria L. Pappas, Ioanna Maria Katsimiga, Galini Koutsoula, George D. Broufas

Democritus University of Thrace, School of Agricultural Sciences and Forestry, Laboratory of Agricultural Entomology and Zoology, Orestiada, Greece

e-mail address: mpappa@agro.duth.gr

Abstract. Plants use sophisticated mechanisms to defend themselves against herbivory. Depending on the plant species or cultivar, chemical and mechanical traits can result in different degrees of resistance against a specific herbivorous pest species. Furthermore, different herbivores may differ in the ways they are affected by plant defenses depending on their species, which can be a result of their different feeding modes or mechanisms to withstand effective plant defenses. In this study, we assessed different tomato cultivars which are commercially available in Greece, for their effects on key arthropod pests. Specifically, we conducted performance lab experiments which lasted for either 5 days (short-term experiments) or 4 weeks (long-term experiments) after infestation with 12 tomato cultivars, the two spotted spider mite *Tetranychus urticae*, the tomato russet mite *Aculops lycopersici*, the whitefly *Bemisia tabaci*, and the tomato leafminer *Tuta absoluta*. Our results show considerable variation between the different cultivars in their effects on the performance (survival, oviposition, total number of individuals) of each herbivore. Based on these results we were able to conclude on the two most promising cultivars which are currently being assessed for their effects also on the behavior of the different pests. Eventually, we aim to be able to conclude on resistant tomato cultivars which can be used in Integrated Pest Management (IPM) programs against key tomato pests.

The study was part of the project “Innovations in Plant Protection for sustainable and environmentally friendly pest control, InnoPP - TAEDR-0535675 that is “Funded by the European Union- Next Generation EU, Greece 2.0 National Recovery and Resilience plan, National Flagship Initiative “Agriculture and Food Industry”.

Key words. Insects, mites, preference, resistance, tomato.

Susceptibility of different cucumber genotypes to the sweet potato whitefly *Bemisia tabaci*

Alessia Farina, Marco Di Domenico, Luca M. Girgenti, Giuseppe E. Massimino Cocuzza, Carmelo Rapisarda, Pompeo Suma

Department of Agriculture, Food and Environment; Applied Entomology Division; University of Catania; via S. Sofia, 100; 95123 Catania, Italy

e-mail address: *alessia.farina@unict.it*

Abstract. *Bemisia tabaci* is a significant pest worldwide as it infests numerous plants, ranging from cultivated crops to ornamental and wild species. This whitefly is known for its ability to transmit both persistent circulative and non-circulative viruses to vegetable plants, which severely affect crops belonging to the Solanaceae and Cucurbitaceae families. Exploiting host plant resistance mechanisms provides an additional solution for integrated control (IPM) of this pest, as plants' morphological, chemical and physical traits can influence the pest's colonization, feeding, and oviposition. In the frame of research aimed at improving integrated management strategies against *B. tabaci*, experimental trials were conducted in Sicily (Italy) within the activities of the EU Horizon 2020 project "Emerging viral diseases in tomatoes and cucurbits: implementation of mitigation strategies for durable disease management (VIRTIGATION)" (<https://www.virtigation.eu/>). This study considered an evaluation of the most promising cucumber accessions identified by Stichting Wageningen Research and maintained at the Centre for Genetic Resources (Wageningen University & Research, The Netherlands), already laboratory screened by the University of Greenwich (all partners in the project). Specifically, through no-choice and multiple choice tests carried out under semi-field conditions, this work aimed to validate the performance of the investigated cucumber genotypes, focusing on their attractivity to *B. tabaci*, their availability for oviposition, and their ability to support the development of immature stages of the whitefly. Our results showed that some of the tested genotypes are promising in both tests, as they appear to exert lower susceptibility to *B. tabaci*. However, further investigations are needed and will be conducted under laboratory conditions to better understand the mechanisms of plant resistance.

Key words. Whiteflies, preference, cucumber, resistance, IPM.

Effects of different melon genotypes on the whitefly *Bemisia tabaci*

Maria L. Pappas¹, Dimitra Ouzouni¹, Galini Koutsoula¹, Evangelia Karakosta^{1,2}, Anastasia Tsagkarakou², George D. Broufas¹

¹ Democritus University of Thrace, School of Agricultural Sciences and Forestry, Laboratory of Agricultural Entomology and Zoology, Orestiada, Greece;

² Hellenic Agricultural Organization - DIMITRA, Institute of Olive Tree, Subtropical Crops and Viticulture, Crete, Greece

e-mail address: gbroufas@agro.duth.gr

Abstract. In the context of Integrated Pest Management (IPM), plant resistance is a useful method to combat crop arthropod pests. However, we still have limited data on the effects of different cultivars/genotypes of several crop species against herbivores, either these are commercially available or not. In that sense, melon is such crop species for which we know relatively little. Within this study, we assessed the effects of commercial melon cultivars as well as genotypes from the national genebank for their resistance to the whitefly *Bemisia tabaci*, a key pest in melon and other numerous crops. We conducted performance experiments to study the effects of the different melon genotypes on the survival and egg number of the whitefly, as well as host preference experiments to choose the most promising (i.e. resistant) ones. We also performed long-term performance experiments i.e. lasting for approx. one month after infestation of the plants with the whiteflies, to assess melon resistance effects on the whitefly population. Our results are promising, depicting at least two genotypes, one commercial and one genotype from the national genebank, exerting whitefly resistance. Further experiments will explore the underlying mechanisms of plant resistance to *B. tabaci* as well as assess the resistance recorded in field experiments.

The study was part of the project “Innovations in Plant Protection for sustainable and environmentally friendly pest control, InnoPP - TAEDR-0535675 that is “Funded by the European Union- Next Generation EU, Greece 2.0 National Recovery and Resilience plan, National Flagship Initiative “Agriculture and Food Industry”.

Key words. *Cucumis melo*, plant performance, preference, resistance, whiteflies.

New plant-extracted insecticides for integrated control of whiteflies in vegetable protected crops

Blanca Sabarit¹, Stefano Convertini², Marco Di Domenico³, Alessia Farina³, Antonino Fenio⁴, Patricia Gilarte¹, Luca M. Girgenti³, Victor Golyaev⁵, Inge Hanssen⁶, Marlies Huysmans⁷, Guadalupe López¹, Carolina Martínez-Gaitán¹, Giuseppe E. Massimino Cocuzza³, Rani Mertens⁷, Ellen Richter⁸, Carolina Sánchez-Barranco¹, Maria Schmidt⁸, Lise Soetemans⁷, Pompeo Suma³, Hervé Vanderschuren⁵, Kumar Vasudevan⁵, Elise Vogel⁶, Carmelo Rapisarda³

¹ *Fundación para las Tecnologías Auxiliares de la Agricultura – TECNOVA; Avenida de la Innovación 23; 04131 El Alquíán, Almería, Spain*

² *Agrin – Agriculture Innovation; Via Chiatona 62; 74016 Massafra (TA), Italy*

³ *Department of Agriculture, Food and Environment; Applied Entomology Division; University of Catania; via S. Sofia, 100; 95123 Catania, Italy*

⁴ *Corteva Agriscience Italia SRL; Via dei Comizi Agrari, 10; 26100 Cremona, Italy*

⁵ *Katholieke Universiteit Leuven; Oude Markt 13; 3000 Leuven, Belgium*

⁶ *De Ceuster Meststoffen NV - DCM; Bannerlaan 79; 2280 Grobbendonk, Belgium*

⁷ *Proefcentrum Hoogstraten; Voort 71; 2328 Meerle, Belgium*

⁸ *Landwirtschaftskammer Nordrhein-Westfalen; Nevinghoff 40; 48147 Münster, Germany*

e-mail address: bsabarit@fundaciontecnova.com

Abstract. Plant-extracted insecticides, often referred to as botanical insecticides, are natural compounds derived from plants showing insecticidal properties. These substances are gaining attention as environmentally friendly alternatives to synthetic chemical pesticides, and their use is growing in greenhouse vegetable production, where IPM is crucial to maintain high yields and safeguard the quality of the produce. Their use in protected horticulture deserves to be enhanced for ecological (rapid degradation, resulting in a lower risk of long-term contamination, and selectivity towards non-target organisms, including pollinators and natural enemies), but also for technical reasons (less frequent development of resistance, compared to synthetic chemicals, and their alignment with organic farming principles). However, to their best use, plant-extracted insecticides need to be combined with other pest management methods, such as biological control and cultural practices. Also, for an effective application and to prevent pest resistance, different botanical insecticides must be rotated; and this is why a wide portfolio of plant-extracted insecticides must be available. Towards this direction and within the framework of the European project Virtigation (<https://www.virtigation.eu/>), a line of research developed by partners from various countries (Belgium, Germany, Italy and Spain) aimed to test, in semi-field and field experiments, some plant-based insecticides developed by one of the project partners (KULeuven, Belgium), in order to: i) screen their efficacy on the whitefly *Bemisia tabaci*, one of the most important crop pests and virus vectors, ii) evaluate their side effects on non-target insects (natural enemies and pollinators), and iii) plan their possible integration into a comprehensive pest management strategy. Overall results from these tests show good efficacy of the new botanical insecticides on the target pest (especially against adults and nymphs), similar to biological reference treatments and, in some cases, even to synthetic insecticides, as well as their selectivity to beneficial insects.

Key words. Botanical insecticides, *B. tabaci*, efficacy, selectivity, IPM.

Integrated approach to improve the use of biocontrol agents in IPM of key protected crop pests

Anastasia Tsagkarakou¹, Evangelia Karakosta^{1,2}, Angeliki Paspatis¹, Aris Ilias¹, Kostas Mavridis³, Maria Pappas², John Vontas^{3,4}

¹ Hellenic Agricultural Organization - DIMITRA, Institute of Olive Tree, Subtropical Crops and Viticulture, Crete, Greece

² Democritus University of Thrace, School of Agricultural Sciences and Forestry, Laboratory of Agricultural Entomology and Zoology, Orestiada, Greece

³ Foundation for Research & Technology Hellas, Institute of Molecular Biology & Biotechnology, Crete, Greece

⁴ Agricultural University of Athens, Department of Crop Science, Pesticide Science Lab, Athens, Greece

e-mail address: tsagkarakou@elgo.gr

Abstract. Protected crops in Crete and Southern Greece face significant challenges from high pest pressures and the increasing issue of insecticide resistance. We employ an integrated approach to enhance the resilience of beneficial organisms, such as predatory mites (*Amblyseius swirskii*, *Typhlodromus reckii*) and insects (the mirid bug *Nesidiocoris tenuis*), against synthetic pesticides and hostile crops like tomatoes. This is achieved by reducing chemical inputs in combination with the use of biological control agents and cultural practices.

Advanced molecular diagnostics (TaqMan qPCR and Droplet Digital PCR) were employed to monitor insecticide resistance in major pests (*Bemisia tabaci*, *Tetranychus urticae* and *Frankliniella occidentalis*). Resistance mutations were widespread, with some alleles reaching 100% prevalence, demonstrating the critical need for early detection of resistance. Biopesticides (Requiem®, Eradicoat®, Prev-Am®, FLiPPER®) were evaluated for their impact on beneficial arthropods, revealing varied effects. Additionally, wild populations of *N. tenuis* demonstrated genetic variation for pesticide resistance, providing candidates for improved performance through artificial selection.

Tomato genotypes from the National GeneBank were assessed for their impact on pest (*T. urticae*, *B. tabaci*) and predator performance (*T. reckii*). Results demonstrated significant relationships between trichome density and the development or dispersal of both phytophagous and predatory mites, emphasizing the importance of selecting compatible tomato varieties for IPM strategies. Furthermore, companion plants are being evaluated to mitigate plant damage caused by *N. tenuis*. Ongoing experiments aim to optimize IPM by integrating these plants into sustainable pest management frameworks.

This study highlights the importance of integrative research in developing a robust IPM framework that employs data-driven approaches to reduce pest pressures and minimize chemical inputs.

This work was funded by the flagship project “Innovative Plant Protection for Primary Agricultural Production - InnoPP” and the Horizon EU project “NextGenBioPest.”

Key words. Biological control agents, molecular diagnostics, biopesticides, tomato genotypes.

Nectar fermentation by bacteria from the nectar of *Fagopyrum esculentum*: effects on parasitoids

Evgenia Sarakatsani^{1*}, Patrizia Bella¹, Ezio Peri¹, Antonino Cusumano¹, Bart Lievens², Stefano Colazza¹

¹ Department of Agricultural, Food and Forest Sciences, University of Palermo, 90128 Palermo, Italy

² Department of Microbial and Molecular Systems, KU Leuven, B-3001 Leuven, Belgium
e-mail address: evgenia.sarakatsani@unipa.it

Abstract. Predators and parasitoids used for biological control against economically important crop pests often rely on plant resources such as floral and extrafloral nectar for their energy and nutritional requirements. In modern intensively managed crop production systems, such as greenhouses, these important plant-derived resources may be completely or partially absent. The provision of flowering plants with readily accessible and high quality nectar has been proposed as a way of maintaining important biological control agents that rely on this sugar-rich food source. Due to its sugar content, nectar is also a habitat for microbial growth. How microbes alter nectar chemistry and subsequently affect the performance parameters of biological control agents that consume nectar has been largely unexplored. In this study, synthetic nectar was used in longevity bioassays after nectar fermentation by different bacteria from the phylum *Bacillota*, *Pseudomonadota* and *Actinomycetota*, previously isolated from the nectar of a flowering plant known to enhance parasitoid longevity, *Fagopyrum esculentum* (Polygonales: Polygonaceae). We inoculated a mixture of filter-sterilised sucrose solution and casamino acids with different bacterial strains at an optical density of 1 (OD=1). The different nectar media after bacterial fermentation represented the treatments and the non-inoculated synthetic nectar served as the control. The parasitoids were differentially affected by the bacterial fermentation of nectar with positive results mainly from the phylum *Bacillota*. The chemical analysis provided insights into the mechanisms by which chemical modification of nectar by the bacteria may affect the performance of important biological control agents. The results may point to the potential use of nectar-dwelling bacteria in the context of optimising biological control in protected crops.

Key words. Biological control, nectar, parasitoids, *Bacillota*, *Pseudomonadota*, *Actinomycetota*.

Improving biocontrol efficiency by better aligning predator and pest habitats

Enric Vila¹, Pablo Bielza², Amador Rodríguez-Gómez², Luís Manuel Aguilera-Sáez¹, David Herzog³, Ana Arevalo¹

¹ AGROBÍO S.L., Ctra. Nacional 340 Km. 419, 04745-La Mojonera, Almería, Spain

²Departamento de Ingeniería Agronómica, Universidad Politécnica de Cartagena, Paseo Alfonso XIII, 48, 30203 Cartagena, Spain

³ Rijk Zwaan Ibérica S.A., Ctra Viator-PJ.Mami S/N, 04120-Almería, Almería, Spain

e-mail address: evila@agrobio.es

Abstract. Supplementary foods are widely used in augmentative biocontrol programs to support the establishment and conservation of natural enemies. Previously, we developed a diet using three astigmatid mite species that enhanced the establishment of phytoseiids, mirids, and anthocorids. This feeding program successfully established *Orius laevigatus* on pollen-deficient plants such as cucumbers and a hairless tomato mutant developed by Rijk Zwaan Breeding BV.

In the current project, we evaluated a new strain of *O. laevigatus*, specifically selected for better feeding on astigmatids, in combination with supplemental diets. The primary goal was to control *Thrips parvispinus* in commercial pepper greenhouses by modifying the predator's distribution patterns. Unlike *Frankliniella occidentalis*, *T. parvispinus* is more dispersed across leaves, thus reducing *O. laevigatus* efficiency. We also tested whether in-crop feeding could improve the performance of other predators on tomatoes. The objectives were to (1) reduce plant-feeding damage caused by *Nesidiocoris tenuis* and (2) enhance control of *Aculops lycopersici* on mutant tomato cultivars. A randomized block design was implemented in an experimental greenhouse with three tomato varieties, with and without trichomes.

Results showed that the feeding system increased *O. laevigatus* populations on leaves, improving preventative thrips control. Excellent *A. lycopersici* control was achieved on hairless tomato cultivars, where *Transeius montdorensis* was established throughout all plant strata. Additionally, fewer than one-third of *N. tenuis* populations were found at the tops of plants when the in-crop feeding strategy was used, whereas more than 70% were there without it. This reduction helps prevent plant damage, even when predator populations are high and pest numbers are low. We discuss how distribution of food across plants can improve spatial overlap with pests, thereby enhancing predatory efficiency or reducing the risk of plant damage caused by zoophytophagous predators.

Key words. Supplemental diets, genetically selected predators, Phytoseiidae, Miridae, Anthocoridae, Astigmata.

Enhancing biological pest control: olfactory conditioning of parasitoid wasps

Nikoletta Foskolou¹, Matthew Back¹, Joe Roberts¹, Helmut van Emden², Liam Harvey³, Neal Ward³, Tom Pope¹

¹ Harper Adams University, Newport, Shropshire, TF10 9EY, UK

² University of Reading, Whiteknights Road, Reading, RG6 6AU, UK

³ Biobest Group NV, 2260 Westerlo, Belgium

Abstract. Parasitoid wasps are used in biocontrol programmes to suppress pest populations below economic thresholds but can be slow to establish following release. Slow establishment may, in part, be a result of current mass-rearing systems, which do not account for how cognitive processes affect host location, and recognition.

Host-searching behaviour is vital for female parasitoid fitness and relies on chemical cues from their environment following a three-level process: (1) host habitat location using herbivore-induced plant volatiles (HIPVs), (2) host location using HIPVs and other host-originating chemical cues and (3) host discrimination and acceptance using cues directly derived from the host. Learning usually takes the form of an association between a particular odour and the presence of a suitable aphid host which is further enhanced by a successful oviposition experience. Naive parasitoids (no previous oviposition experience) learn to associate the chemical cues of the cuticle of their aphid hosts upon emergence. Thus, the rearing system of aphid host/plant is of great importance as it can lead to efficiency losses upon glasshouse biocontrol releases.

This study examined whether newly emerged *Diaeretiella rapae* wasps were able to associate with their aphid host/plant rearing system, i.e. *Mysus persicae*/Pak choi (= *Brassica rapa* subsp. *chinensis*) or *Brevicoryne brassicae*/Pak choi, in their future oviposition choices, and whether the aphid host or aphid host plant had a greater influence on their choices made by foraging parasitoids.

Key words. Associative learning, olfactory conditioning, rearing systems.

Indirect effects of banker plants through herbivory-induced plant volatiles

Tomoya Tasaki¹, Yuka Okemoto², Karin Nakamura², Norihide Hinomoto¹, Masayoshi Uefune²

¹ *Laboratory of Ecological Information, Graduate School of Agriculture, Kyoto University, Kyoto 606-8502, Japan*

² *Department of Agrobiological Resources, Faculty of Agriculture, Meijo University, Nagoya, Aichi 468-8502, Japan*

e-mail address: hinomoto.norihide.8m@kyoto-u.ac.jp

Abstract. Secondary plants are widely used to enhance the effectiveness of biological control programs. Banker plants are one type of secondary plants which support the early establishment of natural enemies population, providing alternative food, oviposition sites, and shelter both in fields and greenhouses. A kind of spider flowers, *Cleome hassleriana*, is often used as a banker plant for helping the zoophytophagous mirid bug *Nesidiocoris tenuis*, when this is employed as biological control agent against whiteflies and thrips. Many zoophytophagous mirid bugs inject saliva to digest plant tissue and such a wounding mechanism induces plant defense systems. Many studies reported that plants fed by *N. tenuis* release plant species-specific *N. tenuis*-HIPVs (Nt-HIPVs) and Nt-HIPVs facilitate plant-plant communication. However, it is unknown whether Nt-HIPVs from banker plants affect the performance of herbivores. We investigated whether exposure of Nt-HIPVs or HIPVs induced by the two-spotted spider mite *Tetranychus urticae* (Tu-HIPVs) from *C. hassleriana* to tomato plants affects survival and oviposition of *T. urticae* on tomato plants. We show that induced defense of tomato plants facilitated by Tu-HIPVs reduced the number of eggs laid by *T. urticae*, but not of Nt-HIPVs. Our results demonstrate that Tu-HIPVs from *C. hassleriana* can induce plant defense response and reduce *T. urticae* performance. Therefore, *C. hassleriana* may not only maintain the population of *N. tenuis*, but also serve as a dispenser to release HIPVs that activate the defense of tomato plants.

Key words. *Nesidiocoris tenuis*, zoophytophagous, induced defense, indirect defense, plant-plant communication, herbivory-induced plant volatiles.

Posters

(in alphabetical order by presenter)

Optimizing the application of a *Metarhizium brunneum* strain to mitigate iron deficiency in tomato plants

Esther Aguilera Cuenca, Maria José García del Rosal, Enrique Quesada-Moraga, Meelad Yousef-Yousef*

Department of Agronomy, Unit of Excellence María de Maeztu DAUCO, ETSIAM, University of Cordoba, Cordoba, Spain

*e-mail address: z12yonam@uco.es

Abstract. In addition to their primary role as biological control agent, *Metarhizium brunneum* has recently been recognized as excellent biostimulant for its ability to improve plant nutrition. Particularly, it has been demonstrated an alleviation of the iron deficiency symptoms known as “Fe chlorosis”. Plants acquire iron (Fe) through two strategies, Strategy I or II. All plants except those in the Poaceae family use Strategy I which involves the reduction of Fe³⁺ to Fe²⁺ prior to its uptake. In Strategy I plants, the improvement of the Fe nutrition could be partially due to the induction of several physiological responses to Fe deficiency like the increase of the ferric reductase activity (FRA) responsible of the reduction of Fe⁺³ to Fe⁺² in the soil. This study is aimed to explore the possible role of *M. brunneum* (strain EAMa 01/58-Su) as growth promoter and as inducer of the Fe deficiency responses in tomato plants (Strategy I). For this purpose, tomato plants grown in a hydroponic system under iron sufficiency and deficiency conditions were inoculated with *M. brunneum* strain EAMa 01/58-Su by three inoculation methods: root immersion (RI), foliar spraying (FS), and seed dressing (SD). Chlorophyll content (SPAD) and FRA were daily determined as well as the relative expression of several key genes related to Fe acquisition; *FRO2* (Ferric Reductase), *IRT1* (Iron transporter) and *FER* (bHLH transcription factor) in roots by qRT-PCR. The results showed a clear effect of RI and SD on FRA. Besides this, the relative expression of Fe related genes increased at different time points depending on the inoculation method used, leading to a 20% enhancement in total plant fresh weight compared to the control when the SD method was applied. This work provides novel insights into the potential of *M. brunneum* (strain EAMa 01/58-Su) as a biostimulant and growth promoter.

Key words. Entomopathogenic fungi, biostimulant, inoculation method, growth promotion, ferric reductase activity, endophytic colonisation.

***Beauveria bassiana* endophytic colonization alters volatile profiles without affecting lacewing oviposition and is modulated by plant genotype**

María Cuenca-Medina¹, Raquel Rodríguez-Solana^{2,3}, José Manuel Moreno-Rojas⁴, Rafael Alcalá-Herrera⁵, Enrique Quesada-Moraga¹, Natalia González-Mas¹

¹ Department of Agronomy, ETSIAM, University of Cordoba, Campus Universitario Rabanales, Cordoba, Spain

² Andalusian Institute of Agricultural and Fisheries Research and Training (IFAPA), Rancho de la Merced, 11471 Jerez de la Frontera, Spain

³ MED—Mediterranean Institute for Agriculture, Environment and Development & CHANGE—Global Change and Sustainability Institute, Faculdade de Ciências e Tecnologia, Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal

⁴ Department of Agroindustry and Food Quality, Andalusian Institute of Agricultural and Fisheries Research and Training (IFAPA), Alameda del Obispo, Avenida Menéndez Pidal, S/N, 14004 Cordoba, Spain

⁵ Zoology and Entomology Unit, School of Forestry Engineering and Natural Resources, Polytechnic University of Madrid, Campus Ciudad Universitaria, S/N, 28040 Madrid, Spain
e-mail address: z22goman@uco.es

Abstract. Biological control strategies integrating entomopathogenic ascomycetes (EA) and natural enemies are a key component for Integrated Pest Management (IPM) programs. Among EA, *Beauveria bassiana* has demonstrated efficacy against aphids, targeting them through integumentary contact, but also as a plant endophyte, colonising systemically the crop. This endophytic colonisation can alter the chemical ecology of the plant, influencing multitrophic interactions in the context of IPM strategies. Additionally, the degree of endophytic colonisation can vary among plant species and fungal strains, raising questions about possible variations among different cultivars of the same host plant species. Hereby, this study evaluates endophytic colonisation and its effects on the volatile profiles of three different melon cultivars (*Cucumis melo* L. cv. Galia, Futuro and Rinconete) by the AE *B. bassiana*. Colonisation rates ranged from 73.0% to 85.0%, showing the cv. Galia the highest percentage. Analyses revealed a core set of two VOCs (cis-3-hexenal and N,N-dimethyl-1-dodecanamine) common across all cultivars endophytically colonised by *B. bassiana*. Additionally, cultivar-specific VOCs such as cis-3-hexenol and β -phellandrene (cv. Galia), cinnamaldehyde and cinnamyl alcohol (cv. Futuro), and styrene and acetophenone (cv. Rinconete) were identified. Understanding these changes associated to the plant genotype is essential for optimising the behaviour of natural enemies within IPM programs. In a second experiment, the impact of colonisation on the multitrophic system involving *C. melo* cv. Galia, *Aphis gossypii*, and *Chrysoperla carnea* was assessed by olfactometer bioassays. Lacewings did not exhibit a distinct preference for any treatment. However, volatile analysis revealed quantitative differences in the volatile profile from *B. bassiana*-colonised plants and a different volatile response of these plants when they were infested by the aphids, which may influence other plant-insect interactions. This work underscores the potential of endophytic EA combined with other natural enemies in IPM programs.

Key words. Entomopathogenic fungi, *Aphis gossypii*, *Chrysoperla carnea*, VOCs, GC-MS, chemometric analysis.

The challenge of controlling the Tomato russet mite (*Aculops lycopersici*) in tomato greenhouse production

Marko Devetak, Sara Hobljaj, Mojca Rot

Institute of Agriculture and Forestry Nova Gorica; Pri hrastu 18 5000 Nova Gorica; Slovenia

Abstract. Tomato russet mite [*Aculops lycopersici* (Masse, 1937)] (Acari: Eriophyidae) is considered a common pest of several Solanaceae crops worldwide. In recent years, increasing temperatures and the lack of effective management strategies have intensified pest pressure in the open field and in the greenhouse tomato cultivation in Slovenia. Since there is no available control measure against this pest in Slovenia, based on acaricide sprays, researchers tend to be more engaged in developing alternative control strategies. During the years 2022 and 2023 we tested various active ingredients, including sulphur and orange oil, as well as the entomopathogenic fungus *Beauveria bassiana* strain ATCC 74040. The efficiency of acaricides containing hexythiazox, which is authorised for the control of the Two-spotted spider mite, *Tetranychus urticae* Koch, was also tested. Spraying experiments were performed in the tomato greenhouse production area in Slovene Istria (the northern part of the Istrian peninsula). In both years repeated treatments with sulphur significantly reduced the eriophyid mite infestations on tomato. The efficiency of sulphur treatments in 2022 and 2023 reached 75.0% and 87.5%, respectively. The other products used in the experiments had no significant effect in reducing the mite population, and the efficacy of the treatments did not differ from the untreated controls. The overall success of Tomato russet mite control was closely related to weather conditions. High temperatures and heat stress in the year 2022 notably decreased the efficacy of treatments against eriophyid mites.

Key words. *Aculops lycopersici*, tomato greenhouse production, sulphur, heat stress.

Ecological infrastructures outside greenhouses – impact on Hymenoptera Parasitica abundance and diversity

Elisabete Figueiredo^{1,3}, Robyn Payne², António Santos², Sílvia Pina⁴, José Carlos Franco^{2,3}

¹ LEAF - Linking Landscape, Environment, Agriculture and Food, Instituto Superior de Agronomia, Universidade de Lisboa. Tapada da Ajuda, 1349-017 Lisboa, Portugal

² CEF - Forest Research Centre, Instituto Superior de Agronomia, Universidade de Lisboa. Tapada da Ajuda, 1349-017 Lisboa, Portugal

³ Associate Laboratory TERRA, Instituto Superior de Agronomia, Universidade de Lisboa. Tapada da Ajuda, 1349-017 Lisboa, Portugal

⁴ BIOPOLIS Program in Genomics, Biodiversity and Land Planning; CIBIO - Research Centre in Biodiversity and Genetic Resources, Associate Laboratory InBIO, Instituto Superior de Agronomia, Universidade de Lisboa. Tapada da Ajuda, 1349-017 Lisboa, Portugal

e-mail address: elisalacerda@isa.ulisboa.pt

Abstract. Plant ecological infrastructures are important for the success of biological control, providing pollen, nectar, alternative prey and hosts for parasitoids and predators, as well as shelter. Within the PRIMA ASTER project, a two-year study was carried out in 2023-2024 to assess the abundance and diversity of the Hymenoptera Parasitica in the surrounding of two greenhouses used for tomato production in a farm, in the Oeste region, Portugal. In the first year, four seasonal samplings were conducted, one in the end of spring, two in the summer, and one in autumn, using four Malaise traps outside each greenhouse. Samplings were repeated in the second year, after installing a strip of selected plants with different flowering periods and strata (herbs and shrubs) outside one of the greenhouses, as ecological infrastructures (*Foeniculum vulgare*, *Coriandrum sativum*, *Rosmarinus prostratus*, *Borago officinalis*, *Viburnum tinus*, *Calluna vulgaris*, *Thymus vulgaris*, *Phacelia tanacetifolia*, *Helichrysum italicum*, *Lavandula stoechas*, and *Lobularia maritima*). Data is being analysed, aimed at assessing the seasonal dynamics of wasp captures, as well as the diversity of hymenopteran families and their relative importance. The potential effect of the installed ecological infrastructure will be also evaluated.

Key words. Parasitoids, protected crops. tomato, biological control.

Possibility of control of *Botrytis cinerea* on *Begonia semperflorens* by *Trichoderma atroviride* SC1

Bogoljub Kandić¹, Jelena Latinović¹, Nika Savović¹, Tatjana Popović Milovanović², Nedeljko Latinović¹

¹ *University of Montenegro, Biotechnical Faculty, Mihaila Lalića 15, 81000 Podgorica, Montenegro*

² *The Institute for Plant Protection and Environment (IPPE), Teodora Drajzera 9, 11000 Beograd, Srbija*

e-mail address: kandic.b@ucg.ac.me

Abstract. A decay of the plant species *Begonia semperflorens* was observed in several greenhouses in the territory of the municipality of Podgorica during the months of March and April 2024. Symptoms were recorded on leaves and flowers as water-soaked spots which then turn brown and zonate over time. The phytopathogenic fungus *Botrytis cinerea*, the cause of gray mold disease, was isolated from infected parts of the plant in the Laboratory of phytopathology of the Biotechnical Faculty of Podgorica. The fungus survives in plant debris and is favored by high moisture, low temperatures and low light levels in greenhouses. *B. cinerea* is a fungus that develops resistance to syntetic fungicides relatively quickly, but also, fungicides can often leave traces on the plant leaves which represent a problem in sales because of the reduction of the plants' market value. The efficacy of *Trichoderma atroviride* SC1 (Vintec[®]) toward the obtained *B. cinerea* isolate was tested *in vitro*. Efficacy was assessed by measuring the diameter and surface area of the developed pathogenic fungus colony in the treatment compared to the control. Three days after inoculation, *T. atroviride* SC1 disabled the growth of *B. cinerea* on PDA in Petri dishes, with the efficiency percentage of 65.7%. The sixth day after the inoculation, *T. atroviride* SC1 intensively sporulated on the surface of the *B. cinerea* colony and completely stopped its development. Fungi from the genus *Trichoderma* are soil microorganisms that stimulate the development of the root system of treated plants. The high degree of efficacy of *T. atroviride* against *B. cinerea* in *in vitro* tests in this study, indicates its potential application in Montenegrin flower production by mixing with the substrate for growing or spraying plants with suspension of the biofungicide.

Key words. *Begonia semperflorens*, gray mold, greenhouses, biological control.

Characterization of a local *Bacillus thuringiensis* isolate (*BtTuM1*) and its potential as an entomopathogenic agent against *Tuta absoluta*

Mahmut Mete Karaca¹ Şebnem Tireng Karut², İsmail Döker³, Kamil Karut¹, Cengiz Kazak³

¹ Çukurova University, Agricultural Faculty, Department of Plant Protection, Laboratory of Insect Biotechnology, Adana, Turkey

² Ministry of Agriculture and Forestry, Biological Control Research Institute, Adana, Turkey

³ Çukurova University, Agricultural Faculty, Department of Plant Protection, Laboratory of Acarology, Adana, Turkey

Abstract. The tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae), is a major pest in tomato cultivation, causing yield losses of up to 100% in Turkey and worldwide. This pest damages all above-ground plant organs. Although chemical control is commonly used, its efficacy is limited due to the pest's endophytic larval lifestyle, high biotic potential, multivoltine development, and increasing resistance to insecticides. Therefore, sustainable strategies such as integrated pest management (IPM), that includes biological control, are essential for effective management of this pest. The integration of biopesticides, such as those containing *Bacillus thuringiensis* (*Bt*) or other microorganisms, into IPM programs offers significant benefits. These biopesticides are environmentally friendly, support natural enemies, and reduce potential non-target effects. Additionally, the use of local natural enemies, including parasitoids, predators, and microbial pesticides, further minimizes undesirable ecological impacts. This study evaluated the potential of a local *Bt* isolate (*BtTuM1*), obtained from *T. absoluta* larvae collected in Muğla Province (Turkey), for use in biological control of this pest. Laboratory analyses assessed the isolate's phenotypic, genotypic and pathogenic characteristics. *BtTuM1* showed robust growth on various media, including Nutrient Agar (NA), Sucrose Nutrient Agar (SNA), King B (KB), Yeast Dextrose Calcium Carbonate Agar (YDCA), and Trypticase Soy Agar (TSA), forming large, circular, flat colonies with wrinkled surfaces and yellowish-cream coloration. The isolate was determined to be Gram-positive based on a potassium hydroxide (KOH) test and oxidase-positive as indicated by a blue reaction on oxidase test paper. Spore and crystal staining revealed green-stained spores and purple crystals within red vegetative cells under light microscopy (100x magnification). Molecular analyses confirmed the presence of *cry1*, *cry2*, and *vip3* toxin proteins, which are effective against lepidopteran pests. Bioassay results demonstrated that *BtTuM1* caused 70% mortality in *T. absoluta* neonate larvae within four days at a concentration of 10⁸ cfu/mL. These results suggest that the *BtTuM1* isolate has significant potential for incorporation into IPM strategies targeting *T. absoluta*.

Key words. Tomato leafminer, *Bacillus thuringiensis*, entomopathogen, insecticidal toxin, IPM.

Magnesium hydroxide and selected yeast strains as alternative substances applied towards limitation of potato light blight symptoms

Jolanta Kowalska, Joanna Krzysińska

Institute of Plant Protection – National Research Institute, Dep. of Organic Agriculture and Environmental Protection, Poznan, Poland

e-mail address: J.Kowalska@iorpib.poznan.pl

Abstract. *Phytophthora infestans*, a significant pathogen in organic farming, particularly affects potato crops. Researchers are exploring alternative control methods, including the use of magnesium hydroxide (MH), a basic substance approved for organic farming. Laboratory (*in vitro*) and greenhouse (*in planta*) tests were conducted to assess the effectiveness of MH (125–500 µg/ml) in inhibiting the pathogen's growth. While 125 µg/ml had no effect, higher concentrations (250 and 500 µg/ml) significantly reduced mycelial growth by over 16% and 30%, respectively. MH also inhibited yeast growth which were tested against this pathogen, particularly *Saccharomyces cerevisiae*, while *Naganishia albidosimilis* and *Torulaspora delbrueckii* showed reduced but continued growth. MH (at 125 g/100 l water) shows potential for managing late blight in combination with these yeasts. Greenhouse trials, including low copper doses, have been completed, and field trials with varied strategies and potato varieties are planned.

Key words. Basic substances, *P. infestans*, potato, organic farming, integrated protection, yeast.

Biological control assays with entomopathogenic fungi against the greenhouse thrip *Heliothrips haemorrhoidalis*

Quentin Zimmermann¹, Corentin Descombes¹, Vincent Goldschmid², François Lefort¹

¹ Plants and Pathogens Group, Research Institute Land Nature Landscape, HEPIA Geneva School of Engineering Architecture and Landscape, HES-SO University of Applied Sciences and Arts Western Switzerland, 150 route de Presinge, 1254 Jussy, Switzerland.

² Conservatory and Botanical Garden of Geneva, Chemin de l'Impératrice, Case postale 71 1292 Chambésy, Switzerland.

e-mail address: francois.lefort@hesge.ch

Abstract. The Conservatory and Botanical Gardens of Geneva (CJBG), run under the organic agriculture label of BioSuisse, has been battling without success an unidentified thrips damaging its greenhouse collections since 2016. The infestation reached a critical threshold, prompting the use of entomopathogenic fungi from the Plants and Pathogens laboratory of HEPIA, which had proven effective in combating other insect pests. The 11 fungal isolates tested included *Beauveria bassiana*, *Metarhizium anisopliae*, *Akanthomyces lecanii* (= *Verticillium lecanii*), and *Isaria fumosorosea*, along with a commercial fungal biopesticide previously used by the CJBG.

The greenhouse environment was analyzed to track temperature and humidity, and a list of plants affected by thrips was compiled. The thrips were identified as *Heliothrips haemorrhoidalis*, a common greenhouse pest. Temperature conditions were considered when selecting the most effective fungal isolates, with trials identifying six isolates that performed best. Mortality pre-tests were conducted on *Phaseolus vulgaris* beans to assess the viability of thrips, using an immersion method proven effective in the laboratory.

The first screening trial showed that *B. bassiana* isolate 2.1 achieved a significant 75% mortality rate. The second in vitro trial, conducted at concentrations ranging from 10⁵ to 10⁸ CFU/mL with the most effective isolates from the first trial (*B. bassiana* 1.1 and 2.1, and *M. anisopliae* 33.1 and 34.2), showed a mortality rate of 85% at the 10⁸ CFU/mL concentration. Lethal concentration (LC50 and LC80) values were determined for each isolate, with isolate 1.1 showing the lowest LC80. A semi-in vitro trial with isolates *B. bassiana* 1.1 and *M. anisopliae* 33.1 on infested bean plants showed promising results: isolate 1.1 achieved 84% mortality and isolate 33.1 reached 76%. An in vivo trial at CJBG, on greenhouse plants, with isolate 1.1 showed 75% mortality after 8 days. These results suggest that further trials with isolates 1.1 and 33.1 are necessary before considering approval as a phytosanitary product.

Key words. *Beauveria bassiana*, biocontrol, greenhouse thrip, *Heliothrips haemorrhoidalis*, *Lecanicilium lecanii*, *Metarhizium anisopliae*, *Isaria fumosorosea*.

Combination of semiochemicals and entomopathogenic fungi for the control of *Frankliniella occidentalis*

Corentin Descombes¹, Charles Jean-François Chappuis², Yannick Barth¹, François Lefort¹

¹ *Plants and Pathogens Group, Research Institute Land Nature Landscape, HEPIA Geneva School of Engineering Architecture and Landscape, HES-SO University of Applied Sciences and Arts Western Switzerland, 150 route de Presinge, 1254 Jussy, Switzerland.*

² *Changins, HES-SO University of Applied Sciences and Arts Western Switzerland, Route de Duillier 50, Case postale 1148, 1260 Nyon 1, Switzerland.*

e-mail addresses: francois.lefort@hesge.ch; charles.chappuis@changins.ch

Abstract. Thrips (Thripidae) are phytophagous insects with *Frankliniella occidentalis* (Western flower thrips or WFT) and *Thrips tabaci* (Onion thrips) recognized as the most damaging species to crops. They feed by piercing and sucking on the plant tissues, causing both direct damage through feeding and indirect damage by transmitting viruses. Thrips can develop resistance to phytosanitary products quickly, amplifying their negative impact on agriculture. Hence, investigating biological alternatives, such as biopesticides, is imperative to mitigate the impact on non-target populations, consumers, and to suppress resistance development. Entomopathogenic fungi (EPF) emerge as promising biopesticides. As the application of EPF through inundative spraying for WFT control requires a substantial inoculum that results in high treatment costs, an alternative approach would be to attract WFT by a semiochemical into a trap containing EPF spores, facilitating the infection of conspecifics. Therefore, it is crucial to identify the attractive compounds of WFT, that are compatible with the fungal strains. This study aimed to lay the groundwork for the development of autoinoculation of EPF against WFT. Highly pathogenic fungal strains for thrips were exposed to semiochemicals to assess the fungal growth inhibition. Fungistatic capacities were observed for all of tested molecules, except p-anisaldehyde 10% and verbenone 1%. Geraniol, nerol, and linalool exhibited pronounced deleterious effects at 10%. Verbenone, p-anisaldehyde, methyl isonicotinate, and neryl (S)-2-methylbutanoate were weak inhibitors of fungal growth, particularly on isolates of *Akanthomyces lecanii* (Bb1), *Metarhizium anisopliae* (10.1), and *Beauveria bassiana* (11.4). Visual assessments indicated that *B. bassiana* isolate (2.1) and *M. anisopliae* isolates (32.1, 33.1, and 34.2) displayed the greatest mean inhibitions. Notably, the proprietary isolate Bb1 caused a statistically significant population decrease. This study has successfully identified semiochemical molecules with a weak fungistatic effect against fungal strains suitable for controlling *F. occidentalis* and also identified a fungal strain with potential utility in WFT control.

Key words. Semiochemicals, entomopathogenic fungi, auto-dissemination control strategy *Frankliniella occidentalis*.

Compatibility of biological control agents in the *Agaricus bisporus* production system

Jelena Luković¹, Svetlana Milijašević-Marčić¹, Ljijana Šantrić¹, Nikola Grujić², Ivana Majić³, Dejan Marčić¹, Ivana Potočnik¹

¹ Institute of Pesticides and Environmental Protection, Banatska 31b, 11080, Belgrade, Serbia

² University of Belgrade - Faculty of Agriculture, Nemanjina 6, 11080, Belgrade, Serbia

³ Faculty of Agrobiotechnical Sciences Osijek, Josip Juraj Strossmayer University of Osijek, Vladimira Preloga 1, 31000, Osijek, Croatia

e-mail address: jelena.lukovic@pesting.org.rs

Abstract. Understanding ecological interactions among cohabiting microorganisms after their introduction in the mushroom cultivation cycle is essential for improving both the quantity and quality of products. In addition, pest and disease management using biological control agents (BCAs) is also compatible with organic agriculture and represents an environmentally safe alternative, able to reduce the use of chemical pesticides. As of late, compost green mould, caused by *Trichoderma aggressivum*, has become a major fungal disease of button mushrooms. Relationships (synergistic/antagonistic/additive) between the following BCAs: bacterium *Bacillus amyloliquefaciens* B-241, actinobacterium *Streptomyces flavovirens* A06, and a commercial population of entomopathogenic nematode *Steinernema feltiae* in the control of *T. aggressivum* were evaluated *in vivo*. Their impact on mushroom yield was additionally assessed. The synergy factor (SF) was calculated as a ratio between the observed and expected impact on yield or the efficacy in pathogen suppression. The experiment was conducted under conditions of artificial inoculation with *T. aggressivum* after co-inoculation of these microorganisms. Satisfactory control of *T. aggressivum* was achieved by all tested microorganisms. The study revealed an additive interaction after simultaneous application of the bacterium *B. amyloliquefaciens* B-241 and actinobacterium *S. flavovirens* A06 in their efficacy against the pathogen. Similarly, additive relationships in efficacy against *T. aggressivum* were confirmed between the EPN population and each of the strains of the beneficial bacterium or actinobacterium. Regarding the impact on yield, synergistic interaction was detected between the two microorganisms, as well as between each beneficial microorganism and EPN *S. feltiae*. Since the results revealed compatibility among the tested BCAs in the mushroom cropping cycle, their synchronous application is recommendable.

Key words. *Bacillus amyloliquefaciens*, *Streptomyces flavovirens*, *Steinernema feltiae*, *Trichoderma aggressivum*, beneficial microorganisms, button mushroom.

Response of *Trichoderma* green mould disease agents in oyster mushroom to the essential oils from four medicinal plants

Jelena Luković, Svetlana Milijašević-Marčić, Biljana Todorović, Rada Đurović-Pejčev, Ivana Potočnik

¹ *Institute of Pesticides and Environmental Protection, Banatska 31b, 11080, Belgrade, Serbia*
e-mail address: jelena.lukovic@pestring.org.rs

Abstract. Production of oyster mushrooms [*Pleurotus ostreatus* (Jacq.) P. Kumm.] is severely impacted by various *Trichoderma* species, which cause green mould disease. Biopesticides based on essential oils offer a potential alternative to synthetic pesticides for disease prevention in crop protection. Four essential oils extracted from medicinal plants grown in Serbia, namely thyme (*Thymus serpyllum* L.), basil (*Ocimum basilicum* L.), yarrow (*Achillea millefolium* L.), and St. John's wort (*Hypericum perforatum* L.), were assayed for their *in vitro* fungicidal properties against two *Trichoderma* species isolated from oyster mushrooms substrate (*Trichoderma pleuroti*, strain KM11, and *T. pleuroticola*, strain KM12, 2018, North Macedonia). The oils were tested using the contact microdilution and the fumigant macrodilution method with either pathogen mycelial inoculum or spore suspension. The minimum fungicidal concentration (MFC), minimum inhibitory concentration (MIC), and percentage of mycelial growth inhibition (PGI) were determined. The thyme essential oil was lethal for both species when the contact microdilution method was used at 12.5 $\mu\text{l mL}^{-1}$ (MFC), while no fungicidal effect of the remaining three oils was found at the selected concentrations (MFC > 25 $\mu\text{l mL}^{-1}$). Furthermore, no fungicidal effect of either oil was recorded on any tested pathogen using the fumigant method (MFC > 0.32 $\mu\text{l mL}^{-1}$ of air phase). Three oils (thyme, basil, and yarrow) showed fungistatic contact activity against both *Trichoderma* species, while two oils (thyme and basil) showed fungistatic fumigant activity at various MIC values. The strongest contact activity on both species was shown by the thyme oil (MIC = 1.56 $\mu\text{g mL}^{-1}$), while the oils of basil and yarrow exhibited a slightly lower antifungal activity. The basil oil was found to demonstrate the strongest fumigant activity against both pathogens at various MIC values with PGI in a range from 50.73 to 100%. The St. John's wort oil stimulated mycelial growth of both species. These essential oils could be recommended for further *in vitro* and *in vivo* testing.

Key words. *Thymus serpyllum*, *Ocimum basilicum*, *Achillea millefolium*, *Hypericum perforatum*, *Trichoderma* species, essential oils.

Integrated control strategies for root-knot and pin nematodes in carrot and parsley cultivation in Croatia

Ivana Majić¹, Ankica Sarajlić¹, Branimir Nježić²

¹ Josip Juraj Strossmayer University of Osijek, Faculty of Agrobiotechnical Sciences Osijek, Vladimira Preloga 1, Osijek, Croatia

² University of Banja Luka, Faculty of Agriculture, Bulevar vojvode Petra Bojovića 1A, Banja Luka, Bosnia and Herzegovina

e-mail address: imajic@fazos.hr

Abstract. The management of plant-parasitic nematodes in root vegetable crops requires an integrated approach, as chemical nematicides are not permitted in Croatia. This study investigated the impact of crop rotation and biological treatments on nematode populations in carrot and parsley cultivation. Root-knot nematodes (*Meloidogyne* spp.) are highly damaging pests, causing severe stunting, gall formation, and deformation in carrots, leading to a complete loss of market value. In greenhouse production in Baranja, Croatia (2012–2013), high populations of *Meloidogyne* sp. were detected in carrots, peppers, and tomatoes. Due to limited crop rotation options in greenhouses, biological approaches were tested in 2013–2014 in Vardarac (Baranja), Croatia. Preparations containing beneficial microorganisms, fermented plant extracts, and rock dust were used. *Meloidogyne hapla* was identified as the dominant species, with an average population density of 63–121 nematodes per 100 mL of soil. Significant differences in carrot yield were observed between treatments, highlighting the potential of biological control methods. A field study in Tvrđavica (Baranja), Croatia (2016) examined the effects of a four-year crop rotation on *M. hapla* populations and assessed the efficacy of the bionematicide NemaKey™ against *Paratylenchus bukowinensis* (pin nematode). Introducing cabbage into the rotation reduced *M. hapla* populations, but NemaKey™ failed to suppress *P. bukowinensis*, which reached 217–920 nematodes per 100 mL of soil at harvest, causing a minimum 50% yield loss in carrots and parsley. These findings highlight the need for improved integrated nematode management strategies in vegetable production, particularly in greenhouse systems where crop rotation is limited. This study is the first report of significant economic damage caused by *P. bukowinensis* in Croatia, emphasizing the necessity for further research into effective control measures.

Key words. *Meloidogyne hapla*, *Paratylenchus bukowinensis*, Crop rotation, bionematicide.

Investigating nematode challenges in *Agaricus bisporus* cultivation: A field analysis

**Ivana Majić¹, Ankica Sarajlić¹, Gabriella Kanižai Šarić¹, Svetlana Milijašević-Marčić²,
Ivana Potočnik²**

¹ Josip Juraj Strossmayer University of Osijek, Faculty of Agrobiotechnical Sciences Osijek, Vladimira Preloga 1, Osijek, Croatia

² Institute of Pesticides and Environmental Protection, Banatska 31b, Belgrade-Zemun, Serbia
e-mail address: imajic@fazos.hr

Abstract. Bacterial-feeding nematodes pose a significant threat to mushroom cultivation, particularly in white button mushrooms (*Agaricus bisporus*). These nematodes contribute to the spread of bacterial blotch on sporophores, cause deformities, and can lead to drastically reduced yields or complete crop failure. A study was conducted to investigate the population density of nematodes and their impact on *A. bisporus*. Samples were collected throughout the production cycle from two mushroom farms in Serbia, including compost (both spawned with *A. bisporus* strain F56 Italspawm and unspawned), casing material, and deformed mushrooms. Nematodes were found exclusively in peat samples, while the compost remained sterile. Before casing, nematode populations in peat were low, less than 10 nematodes per 100 mL of peat. 32 days after casing, an average of 630 nematodes per sample was detected. The genus *Caenorhabditis* was the most dominant, with populations ranging from 100 to 510 nematodes per sample. The second most abundant group belonged to the family Cephalobidae, with densities between 50 and 150 nematodes per sample. Other detected saprophytic nematodes included *Acrobeloides*, *Heterocephalobus*, *Panagrolaimus*, *Plectus*, and diplogasterids. By the 46th day after casing, the nematode population had further increased to an average of 880 per sample. At this stage, peat samples were suspected of nematode infestation as the mushrooms showed deformities, and *Caenorhabditis* sp. were isolated, with densities from 490 to 1500 per sample. Additionally, *Caenorhabditis* sp. was extracted from deformed mushrooms, averaging 10 nematodes per 100 g of mushrooms. The dynamics of these bacterial-feeding nematodes revealed their dominance in the cultivation process, suggesting favourable conditions in mushroom beds for their reproduction and survival. Despite measures like compost pasteurization, casing material disinfection, and farm sanitation, applied in this study, the persistence and rapid multiplication of *Caenorhabditis* species underline their significant threat to mushroom cultivation.

Key words. Bacterial-feeding nematodes, *Caenorhabditis*, Mushroom deformities, Peat infestation, Peat disinfection.

Building up knowledge about *Macropsis* species (Hemiptera: Cicadellidae) associated to blackberry plants in Portugal

Célia Mateus¹, Eugénia de Andrade¹, Frederico Preza¹, Manuel Roque^{1,2}, Pedro Oliveira¹, Dmitri Tishechkin³

¹ Instituto Nacional de Investigação Agrária e Veterinária (INIAV, IP). Av da República, 2784-505 Oeiras. Portugal

² Madre Fruta – Centro de Vendas Hortofrutícolas, Lda, Polo de Inovação da Fataca, 7630-580 Odemira, Portugal

³ Department of Entomology, Faculty of Biology, Moscow State University, Lenin Hills, Moscow 119234, Russia

e-mail address: celia.mateus@iniav.pt

Abstract. An outbreak of the *Rubus* stunt disease occurred in blackberry plants, in the South-West Portugal, in the last decade. The subsequent survey looking up for the vector responsible for its dissemination, revealed the presence of *Macropsis scotti* Edwards (Hemiptera: Cicadellidae) in blackberry plants both in greenhouses and in open field. The transmission of the phytoplasma responsible for the disease was attributed to this leafhopper. Literature is scarce on the bioecology of *M. scotti*, which limits our capacity to manage its occurrence and avoid the spread of the disease. In 2023, the entomological data collected in the region were published: variability of coloration in this species was evidenced, as well as its presence both in cultivated and in wild blackberry plants; detection dates, abundances, number of generations were calculated for three years, taking in consideration however that the sampling periods did not cover the whole year. Research was continued to clarify aspects of its population dynamics. Additionally, other *Macropsis* species were searched for, because *Macropsis* spp. are recognized vectors of the phytoplasma concerned in *Rubus* plants. *M. scotti* is monophagous to blackberry plants, but the producers in the region are concerned that the disease will spread to other *Rubus* crops, such as raspberry, which is economically more important there. The results of this research will contribute to the development of a management strategy for this pest.

Key words. *Rubus* stunt disease, insect vector, *Macropsis* spp., *Macropsis scotti*.

Insights on a new thrips found in the south of Portugal associated to pitayas

Célia Mateus, Frederico Preza

Instituto Nacional de Investigação Agrária e Veterinária (INIAV, IP). Av da República, 2784-505 Oeiras. Portugal

e-mail addresses: celia.mateus@iniav.pt, frederico.preza@iniav.pt

Abstract. Climatic changes raise concerns about water scarcity vs agricultural production in the southern regions of Europe. The interest on producing pitayas, or dragon-fruit (*Selenicereus* sp.), is increasing in the south of Portugal (Algarve region), both in greenhouses and in open field. The crop requires much less water than traditional crops and the price at which the fruits are sold constitute a good economic income for producers. In the summer 2024, a thrips species was detected there for the first time: *Scopaeothrips bicolor* (Hood) (Thysanoptera: Tubulifera), formerly known as *Rhopalothrips bicolor*. Literature places this species in the American continent, in Cactaceae, where economic losses are attributed to it in *Opuntia* (cactus pear) producing fields. This species is now being monitored in pitayas greenhouses in the Algarve, and bioecological data are being registered, as well as its impact on the plants. In the course of this monitoring, other potential pests are also being assessed. Information on phytosanitary issues on pitayas in the region is needed for a quick and effective control, if/ when necessary. Results of this study are presented.

Key words. Dragon-fruit, *Selenicereus* sp., *Scopaeothrips bicolor*, *Rhopalothrips bicolor*.

Aphids and their parasitoids on protected vegetables in Serbia

Olivera Petrović-Obradović¹, Andja Radonjić¹, Željko Tomanović^{2,3}

¹ Faculty of Agriculture, University of Belgrade

² Faculty of Biology, University of Belgrade

³ Serbian Academy of Sciences and Arts

Abstract. Growing vegetables in a protected space (greenhouses, tunnels, etc.) offers numerous advantages over growing in the open field. In the Republic of Serbia, cultivation in protected area is organised on increasing area every year. Vegetables (green bean, pea, paper, cucumber, potato, carrot, celery) in greenhouses are attacked by about 10 pest species of aphids. Some species are highly polyphagous (*Aphis fabae*, *Aphis craccivora*, *Aphis gossypii*, *Aphis nasturtii*, *Myzus persicae*, *Aulacorthum solani*, *Macrosiphum euphorbiae*) some other less polyphagous (*Acyrtosiphon pisum*, *Brevicorynae brassicae* and *Cavariella aegopodii*). They are all cosmopolitan and efficient vectors of plant viruses. They cause serious damage to young plants and species with long growing seasons. For every species short notes on morphology, host plants, biology, virus transmission and primary parasitoids are given. Totally over 30 species of primary parasitoids (Hymenoptera: Braconidae: Aphidiinae) are regulating their abundance (e.g. *Aphidius ervi*, *A. matricariae*, *Binodoxys acalephae*, *B. angelicae*, *B. heraclei*, *Diaeretiella rapae*, *Ephedrus persicae*, *E. plagiator*, *Lipolexis gracilis*, *Lysiphlebus confusus*, *L. fabarum*, *Praon abjectum*, *P. volucre*). The most abundant parasitoids in Serbian glasshouses are *A. matricariae*, *A. ervi*, *D. rapae*, *P. volucre* and *B. angelicae*, which are all commercially produced.

Key words. Biological control, *Aphis fabae*, *Aphis gossypii*, *Macrosiphum euphorbiae*, *Myzus persicae*, *Aphidius ervi*.

Survey of pests and their natural enemies in citrus greenhouse nurseries in Montenegro

Sanja Radopnjić, Snježana Hrnčić

University of Montenegro, Biotechnical Faculty, Podgorica, Montenegro

e-mail address: *sanjar@ucg.ac.me*

Abstract. Citrus is one of the largest fruit industries worldwide, grown in more than 50 countries around the world. It is also a major fruit crop of tropical and subtropical areas. Citrus production plays an important role in the agricultural sector of Montenegro, where it is located in the southern (coastal) part. In this study we present an overview of citrus pests in greenhouse nurseries. During the years 2021-2024, from May to October each year, visual inspections in seven greenhouses (near to Podgorica and in the coastal area of Montenegro) revealed that the most common pests are: *Phyllocnistis citrella*, *Dialeurodes citri*, *Aphis spiraecola* and *Panonychus citri*. Other detected species such as *Toxoptera aurantii*, *Chrysomphalus dictyospermi*, *Coccus pseudomagnoliarum*, *Icerya purchasi*, *Aleurocanthus spiniferus*, *Aleuroclava aucubae*, *Metcalfa pruinosa*, *Cacoecimorpha pronubana*, *Polyphagotarsonemus latus* and *Aceria scheldoni*, are less frequent or sparsely found. Despite chemical applications are frequent in most inspected nurseries, sporadic presence of some predator species was recorded: *Harmonia axyridis*, *Coccinella septempunctata* and *Scymnus* sp. All presented findings should serve as the basis for further studies regarding inventorying of beneficial species and their use in biological control.

Key words. Citrus, nurseries, *Phyllocnistis citrella*, *Dialeurodes citri*, *Aphis spiraecola*, *Panonychus citri*.

New challenges in IPM on tomato: plastics for roofing agrivoltaic greenhouses

Carmelo Rapisarda¹, Marco Di Domenico¹, Alessia Farina¹, Raffaele Giarratana², Luca Maria Girgenti¹, Giorgio Iabichella³, Rania Rachdi¹, Pompeo Suma¹

¹ Department of Agriculture, Food and Environment; Applied Entomology Division; University of Catania; via S. Sofia, 100; 95123 Catania, Italy

² Market Led Srl; Borgo Cavour, 49; 63834 Massa Fermana (FM), Italy

³ Technical office of agronomy; via dei Cedri, 14; 97013 Comiso (RG), Italy

e-mail address: carmelo.rapisarda@unict.it

Abstract. In agrivoltaic greenhouses, which offer a promising solution for sustainable agriculture by combining crop cultivation with renewable energy production, the selection of appropriate plastic covers plays a critical role in balancing agricultural productivity and energy generation. Materials used must allow sunlight to reach the crops while diffusing light, to reduce shadows while promoting plant growth. Plastics used in agrivoltaic greenhouses can transmit wavelengths that are beneficial for photosynthesis (PAR: Photosynthetically Active Radiation), while redirecting other wavelengths to the photovoltaic panels for electricity production. Plastic covers in agrivoltaic greenhouses not only optimize light and temperature for plant growth, but may also play a crucial role in pests and disease management. By controlling environmental factors, especially light spectrum, these covers can create conditions that deter pests and inhibit plant pathogens transmission. The phytosanitary role of innovative plastics, usable in agrivoltaic greenhouses, and their possible role in IPM strategies were investigated on protected tomato crops in Sicily. The effects of these plastics, compared to conventional or other photoselective ones, were tested on some of the key pests of tomato in this region, such as the Lepidoptera *Tuta absoluta* and *Spodoptera littoralis*, the whitefly *Bemisia tabaci* and the mealybug *Phenacoccus solenopsis*. A limiting role by the tested plastics has been noted especially on *B. tabaci*, shown not only by the lower number of adults, but by the reduced reproductive and development capacity of the insect, demonstrated by a lower number of eggs and nymphs on plants grown under the tested plastics. As *B. tabaci* is a major vector of viruses, the effect of these plastics on the spread and severity of virus attacks is also being evaluated. However, the importance of using these new roofing materials in IPM programs for greenhouse horticultural crops is already evident from the data available so far.

Key words. physical control, greenhouse covers, light modification, pest control.

Effect of tomato-mediated soil microbes on the olfactory orientation of greenhouse pest natural enemies

Mariangela Milordo¹, Daniele Nicotra¹, Gaetano Siscaro¹, Vittoria Catara¹, Lucia Zappalà¹, Michele Ricupero¹

¹ Department of Agriculture, Food and Environment, University of Catania, 95123 Catania, Italy

Abstract. Tomato crops are constantly threatened by a number of pests. Root-associated microorganisms, such as plant growth promoting fungi (PGPF) and rhizobacteria (PGPR), are known to enhance plant defenses. However, the role of volatiles emitted by microbial-inoculated tomatoes on the olfactory response of biocontrol agents of tomato pests needs further investigation. The olfactory response of three natural enemies (*Cryptolaemus montrouzieri*, *Eretmocerus eremicus* and *Nesidiocoris tenuis*) used against greenhouse key pests to volatiles emitted by tomato plants previously inoculated with PGPF and PGPR were assessed in a two-way olfactometer in the laboratory. Three commercial fungal strains (*Trichoderma asperellum*, *T. harzianum* and *Beauveria bassiana* ATCC 7404), and six bacterial species (commercial strains of *Bacillus subtilis* and *B. amyloliquefaciens*, and laboratory isolates of *B. spizizenii*, *Pseudomonas fluorescens*, *P. veronii* and *P. gessardii*) were tested after 3 and 7 days of inoculation (doi) in comparison to untreated plants. Tomato emitted volatiles and the expression level of defense-related genes in plant tissues were also assessed through GC-MS and qRT-PCR, respectively. In dual choice tests, *C. montrouzieri* showed significant attraction towards tomato plants inoculated with *B. spizizenii* and *T. asperellum* after 3 and 7 doi, respectively. Conversely, *C. montrouzieri* females were generally repelled by tomato emitted volatiles when inoculated with other microbes. A similar trend was observed with *E. eremicus*. Tomato plants inoculated with *B. bassiana* and *B. subtilis* significantly repelled *N. tenuis* both after 3 and 7 doi. The tomato-emitted volatile profile and the transcriptome of plant defense-associated pathways supported our results. These findings suggest that future research into multitrophic interactions should be conducted when combining microbes with arthropod natural enemies for Integrated Pest Management in greenhouse tomato systems.

Keywords. Biocontrol; microorganisms; mealybug destroyer; tomato; parasitoids; protected crops.

Characterization of a mutation in the eyes of the natural enemy *Orius laevigatus* (Hemiptera: Anthocoridae)

Amador Rodríguez-Gómez, María del Carmen Reche, Ana Belén Abelaira, Virginia Balanza, Pablo Bielza

BioControl Selection Lab, Polytechnic University of Cartagena, Spain

Abstract. *Orius laevigatus* (Fieber) (Hemiptera: Anthocoridae) is a key predator in biological control programs in protected crops, used primarily to control thrips. The eye color of adults of this natural enemy is dark (garnet to black). However, adults with a bright red eye color have been found in a mixture of wild populations, easily recognizable from the rest of the individuals of the species. From these adults, a population carrying this eye mutation was established. Genetic analysis determined that the mutation (*red*) was controlled by a single autosomal recessive allele. The use of this red-eyed mutant strain could be useful as a visible marker for ecological and biological studies.

Key words. Biological control, predator, red eyes, autosomal recessive allele, colour.

Native natural enemies of greenhouse pests in Slovenia

Stanislav Trdan, Tanja Bohinc

University of Ljubljana, Biotechnical Faculty, Department of Agronomy, Jamnikarjeva 101, SI-1000 Ljubljana, Slovenia

e-mail address: *stanislav.trdan@bf.uni-lj.si*

Abstract. In Slovenia, in agricultural practice, only natural enemies from the List of native species of organisms for biological control can be used to control plant pests. This list, which currently includes 38 species of predators, parasitoids and entomopathogenic nematodes, is an integral part of the Regulations on biological control (Official Gazette of the Republic of Slovenia, no. 45/06), and it can only include native beneficial organisms, which are also an integral part of the EPPO positive list. Since 2006, we have systematically studied the occurrence of native natural enemies in Slovenia, with the aim of enriching the List of native species of organisms for biological control. This presentation will list 31 species of beneficial organisms from the list that can be used in Slovenia for controlling greenhouse pests, and natural enemies recorded in Slovenian greenhouses that cannot yet be used in greenhouses due to the requirements of the Regulations on biological control.

Key words. Biological control, EPPO positive list, Slovenia, greenhouses.

Diverse spider fauna in Dutch greenhouses: exploring their potential for pest control

Kyra Vervoorn, Khanh Pham, Marcel Heijkoop, Nathan Koedijk, Denise Sewkaransing, Sophie Le Hesran, Ada Leman

Wageningen University and Research, Business Unit Greenhouse Horticulture and Flower Bulbs, Violierenweg 1, 2665 ZG Bleiswijk, The Netherlands

e-mail address: kyra.vervoorn@wur.nl

Abstract. Spiders are common generalist predators in greenhouse environments, where they may play a role in pest suppression. However, the extent of their impact and interactions with other predatory species remain poorly understood. At Wageningen University and Research, we observed a diverse range of spider species in our greenhouses, including members of the family Linyphiidae (e.g. *Erigone dentosa*, *Mermessus denticulatus*, and *Ostearius melanopygius*), as well as species from other families, such as Theridiidae (*Coleosoma floridanum*), Uloboridae (*Uloborus plumipes*) and Salticidae (*Hasarius adansoni*). Some of these species exhibit unique associations with specific crops and microclimatic conditions, suggesting niche differentiation. However, little is known about their predatory behavior, prey preferences, and environmental requirements. Investigating their biology and behavior is essential to understanding their potential for pest control and could provide valuable insights for developing novel integrated pest management (IPM) strategies.

Key words. Spiders, generalist predators, biological control, greenhouse crops.



Integrated Control in Protected Crops, Mediterranean Climate

16th Meeting of the IOBC-WPRS WG

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