

**INTERNATIONAL SYMPOSIUM
ECOLOGY OF APHIDOPHAGA 12**



Belgrade - Serbia, September 9-13, 2013

BOOK OF ABSTRACTS



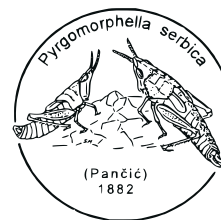
The 12th symposium is dedicated to Dr. Helmut van Emden, a founding member of our group, for his extensive contributions to aphid natural enemy ecology and more than 50 years of support and participation in Aphidophaga.



Serbian Academy of Sciences and Arts



University of Belgrade – Faculty of Biology



Entomological Society of Serbia



Ministry of Education, Sciences and Technological Development of the Republic of Serbia



MikroNik (Nikon authorized representative)

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The Symposium is organized on behalf of:

University of Belgrade – Faculty of Biology
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of the Republic of Serbia**

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Sunday, September 08, 2013

12:00-19:30	Registration	Hotel PALACE – reception desk
20:00-23:00	Welcome garden party	Botanical Garden "Jevremovac" (Takovska St., 43)

Monday, September 09, 2013

08:30	Registration	The Great Hall of the Serbian Academy of Sciences and Arts (Knez Mihailova St., 35)
10:00	Opening ceremony	
	Željko Tomanović, University of Belgrade, local organizer	
	Marko Andjelković, academician, Presidency of Symposium	
	J.P. Michaud, Kansas State University, USA, Steering Committee	
	Jacques Brodeur, Montreal University, Canada	
	Ivica Radović, Deputy Minister for Education, Science and Technological Development	
	Jelena Knežević – Vukčević, Dean of the Faculty of Biology, University of Belgrade	
Session 1 - Community Structure Moderators: Diepenbrock, L.M. and Kindlmann, P.		
12:00-12:20	Ameixa, O.M.C.C., Gerben J. Messelink, G.J. and Kindlmann, P. Nonlinearities lead to qualitative differences in population dynamics of predator-aphid systems.	
12:20-12:35	Grež, A.A. , Zaviezo, T., Rodríguez-San Pedro, A., Hernández, J. and Acuña, P. Effects of landscape composition and heterogeneity on the abundance of native coccinellids and biological control of aphids in alfalfa fields.	

12:35-12:50	Diepenbrock, L.M. and Finke, D.L. Refuge for native lady beetles (Coleoptera: Coccinellidae) in perennial grassland habitats.	The Great Hall of the Serbian Academy of Sciences and Arts (Knez Mihailova St., 35)
12:50-13:05	Lavandero, B. and Tylianakis, J. Genotype matching in a parasitoid-host genotypic food web: an approach for measuring effects of environmental change.	
13:05-13:30	Discussion	
13:30-16:00	Lunch break	Hotel PALACE (Topličin venac St., 23)
16:00-16:15	Janković, M. , Četković, A., Plećaš, M., Tomanović, Ž. and Gagić, V. Aphid and natural enemies densities and parasitism in relation to landscape and field scale complexity – multiscale approach.	
16:15-16:30	Novgorodova, T.A. Do inexperienced ants (Hymenoptera: Formicidae) collecting honeydew recognize aphidophages during their first encounter?	
16:30-16:45	Madeira, F. , Lascio, A. and Pons, X. Are aphids a tool for tracking predator movement between maize and alfalfa using stable isotope analysis?	
16:45-17:15	Discussion	
19:30-	Belgrade fortress – Sightseeing, walking tour	

Tuesday, September 10, 2013		
08:30	Registration and poster mounting	
Session 2 - Coccinellid Ecology Moderators: Michaud, J.P. and Nedvĕd, O.		Hotel PALACE – PANORAMA HALL (Topličín venac St., 23)
09:00-09:20	Michaud, J.P. Parental effects in aphidophagous Coccinellidae and their life history consequences.	
09:20-09:40	Ninkovic, V. Ladybird foraging behaviour an underestimated process.	
09:40-10:00	Dixon, A.F.G. , Sato, S., Kindlmann, P. and Honek, A. Evolution of slow and fast development in predatory ladybirds.	
10:00-10:20	Osawa, N. Maternal investment through sibling egg cannibalism in the ladybird beetle <i>Harmonia axyridis</i> (Coleoptera: Coccinellidae): the role of eggs size.	
10:20-10:35	Suzuki, N. , Osawa, N. and Nishida, T. Asymmetric reproductive interference between specialist and generalist <i>Harmonia</i> ladybirds in Japan.	
10:35-10:50	Nedvĕd, O. , Awad, M., Laugier, G.J.M., Loiseau, A., Piálek, L. and Krejčí, A. Paternity and sperm competition among males of the ladybird <i>Harmonia axyridis</i> (Coleoptera: Coccinellidae).	
10:50-11:15	Discussion	
11:15-11:45	Break	
11:45-12:00	Michaud, J.P. and Vargas, G. Age-specific maternal effects interact with larval food supply to modulate life history in <i>Coleomegilla maculata</i> (Coleoptera: Coccinellidae).	
12:00-12:15	Fassotte, B. , Fischer, C., Durieux, D., Lognay, G. and Verheggen, F.J. First evidence of a volatile sex pheromone in the invasive <i>Harmonia axyridis</i> Pallas (Coleoptera: Coccinellidae).	
12:15-12:30	Godeau, J.F. and Ceryngier, P. Identification of prey items in frass of three ladybird beetles living on black alder.	

12:30-12:45	Beliakova, N.A. and Polykarpova, Y.B. Effects of alternative prey on larval development and reproduction of the lady beetle <i>Cheilomenes sexmaculata</i> (Coleoptera: Coccinellidae).	
12:45-13:00	Razmjou, J. , Ali Zamani, T., Golizadeh, A. and Hasanpour, M. The effect of vermicompost on population growth parameters and fecundity of <i>Hippodamia variegata</i> (Goeze) feeding on <i>Aphis gossypii</i> (Hemiptera: Aphididae)	
13:00-13:15	Borges, I. , Hemptinne, J.L. and Soares, A.O. Contrasting population growth parameters of the aphidophagous <i>Scymnus nubilus</i> and the coccidophagous <i>Nephus reunioni</i> (Coleoptera: Coccinellidae).	
13:15-13:45	Discussion	
13:45-16:00	Lunch break	
16:00-18:00	Poster Session – hotel PALACE – Banquet Hall	
19:30-	Optional program – Cruising and dinner	
Wednesday, September 11, 2013		
8:00-19:30	One day excursion to Zasavica (nature reserve) and Sremski Karlovci	

Thursday, September 12, 2013		
08:30-09:00	Registration and poster mounting	
Session 3 - Aphid Parasitoids Moderators: Vorburger, C. and Kavallieratos, N.G.		Hotel PALACE – PANORAMA HALL (Topličin venac st., 23)
09:00-09:20	Vorburger, C. Symbiont-conferred resistance to parasitoids – implications for biological control.	
09:20-09:40	Heimpel, G. E. , Biondi, A. and Desneux, N. The role of host and host-plant phylogenies in aphid parasitoid specificity	
09:40-10:00	Gagić, V. , Petrović-Obradović, O., Fründ, J., Kavallieratos, N.G.; Athanassiou, C.G.; Starý, P. and Tomanović, Ž. Relationship between aphid traits and generalist-specialist host-use of parasitoids.	
10:00-10:20	Kavallieratos, N.G. , Tomanović, Ž., Petrović, A., Janković, M., Starý, P., Yovkova, M. and Athanassiou, C.G. Parasitoids (Hymenoptera: Braconidae: Aphidiinae) of aphids infesting herbaceous and shrubby ornamental plants in southeastern Europe.	
10:20-10:40	Vamvatsikos, P., van Emden, H. F. and Hardie, J. The flexible responses to plant odor of a generalist aphid parasitoid, <i>Aphidius colemani</i> (Hymenoptera: Braconidae).	
10:40-10:55	Zepeda-Paulo, F.A., Ortiz-Martínez, S., Figueroa, C.C. and Lavandero, B. Adaptive evolution of a generalist parasitoid: Implications for the effectiveness of biological control agents.	
10:55-11:25	Break	
11:25-11:40	Plečaš, M. , Janković, M., Gagić, V., Tomanović, Ž. and Četković, A. Parasitism threshold for effective biological control of cereal aphids in different landscape types.	
11:40-11:55	Dassonville, N. , Thielemans, T. and Rosemeyer, V. Emergence of aphid parasitoids (Hymenoptera: Braconidae and Aphelinidae) at low temperature.	
11:55-12:10	Ben Halima Kamel, M. , Mdellel, L. and Rakhshani, E. Study on some biological parameters of <i>Pauesia antennata</i> Mukerji (Hymenoptera: Braconidae, Aphidiinae), a parasitoid of <i>Pterochloroides persicae</i> (Hemiptera: Aphididae: Lachninae).	
12:10-12:25	Kaiser, M.C. and Heimpel, G.E. Can aphid alarm pheromones induce changes in conspecific aphid reproductive rates?	

12:25-12:40	Sana, Z. and Ben Halima-Kamel, M. Temperature and host plant effects on demographic parameters of <i>Aphidius transcaspicus</i> Telenga (Hymenoptera: Braconidae)	
12:40-13:10	Discussion	
13:10-14:30	Poster Session – hotel PALACE – Banquet Hall	
14:30-16:00	Lunch Break	
16:00-17:30	Optional program	
20:00-	Banquet at Hotel PALACE	

Friday, September 13, 2013

Session 4 - IPM and Biological Control of Aphids

Moderator: Brodeur, J.

09:00-09:15	van Schelt, J. and Messelink, G. The screening of biocontrol agents to control aphids in greenhouses.
09:15-09:30	Guesmi-Jouini, J., Fernandez-Bravo, M., Ben Halima-Kamel, M. , Garrido-Jurado, I. and Quesada-Moraga, E. Effects of temperature and water activity on mycelial growth of nine Tunisian entomopathogenic fungal isolates as biocontrol agents against the artichoke aphid, <i>Capitophorus elaeagni</i> del Guercio (Hemiptera: Aphididae).
09:30-09:45	Kaser, J.M. and Heimpel, G.E. Risk and efficacy in biological control: The introduction of <i>Aphelinus certus</i> (Hymenoptera: Aphelinidae) in North America.
09:45-10:00	Lopes, T. , Bodson, B. and Francis, F. Crop association to improve biological control: a case study on pea and wheat aphids.
10:00-10:15	Ali, A. , Lu, Y.H., Wu, K.M. and Desneux, N. Impact of natural enemies on wheat and cotton aphids in northern China.
10:15-10:45	Discussion
10:45-11:15	Break
11:15-13:00	Closing remarks

Hotel PALACE – PANORAMA HALL
(Topličin venac st., 23)

13:00-14:30	Lunch break
14:30-16:00	Optional program – National Bank of Serbia
20:00-00:00	Optional program – Dinner in bohemian quarter - Skadarlija

ORAL PRESENTATIONS
ABSTRACTS

SESSION 1
COMMUNITY STRUCTURE

MODERATORS: DIEPENBROCK, L.M. AND KINDLMANN, P.

NONLINEARITIES LEAD TO QUALITATIVE DIFFERENCES IN POPULATION DYNAMICS OF PREDATOR-APHID SYSTEMS

Ameixa, Olga M.C.C.¹; Messelink. Gerben J.² and Kindlmann, Pavel^{1,3*}

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Since typically there are many predators feeding on most herbivores in natural communities, understanding multiple predator effects is critical for both community and applied ecology. Experiments of multiple predator effects on prey populations are extremely demanding, as the number of treatments and the amount of labour associated with these experiments increases exponentially with the number of species in question. Therefore, researchers tend to vary only presence/absence of the species and use only one (supposedly realistic) combination of their numbers in experiments. However, nonlinearities in density dependence, functional responses, interactions between natural enemies etc. are typical for such systems, and nonlinear models of population dynamics generally predict qualitatively different results if initial absolute densities of the species studied differ, even if their relative densities are maintained. Therefore, testing combinations of natural enemies without varying their densities may not be sufficient. Here we test this prediction experimentally. We show that the population dynamics of a system consisting of 2 natural enemies (aphid predator *Adalia bipunctata* (L.), and aphid parasitoid, *Aphidius colemani* Viereck) and their shared prey (peach aphid, *Myzus persicae* Sulzer) are strongly affected by the absolute initial densities of the species in question. Even if their relative densities are kept constant, the natural enemy species or combination thereof that most effectively suppresses the prey may depend on the absolute initial densities used in the experiment. Future empirical studies of multiple predator – one prey interactions should therefore use a two-dimensional array of initial densities of the studied species. Varying only combinations of natural enemies without varying their densities is not sufficient and can lead to misleading results.

Key words: *Adalia bipunctata*, *Aphidius colemani*, density-dependence, *Myzus persicae*, parasitoids, predators

EFFECTS OF LANDSCAPE COMPOSITION AND HETEROGENEITY ON THE ABUNDANCE OF NATIVE COCCINELLIDS AND BIOLOGICAL CONTROL OF APHIDS IN ALFALFA FIELDS.

Grez, A.A.^{1*}; Zaviezo, T.²; Rodríguez-San Pedro, A.¹; Hernández, J.³ and Acuña, P.³

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The current trend toward simplification of agricultural landscapes, and the associated loss of perennial natural or semi-natural structures, may decrease natural enemy diversity, particularly native species, which in turn could result in reduced biological control services within crops. We evaluated the effects of landscape composition and heterogeneity at different spatial scales on the relative abundance of native coccinellids associated with alfalfa fields, and also on biological control. The study was carried out near Santiago, Chile, during the 2010 and 2012 growing seasons. Ten non-overlapping landscapes were selected and their composition and heterogeneity were characterized at 1000, 500 and 250 m from a focal alfalfa field. Coccinellids and aphids were sampled in each alfalfa field, in spring, summer and autumn. In total, we collected almost 9,000 coccinellids, 84% comprising six exotic species, and 16% comprising 13 native species. The only significant relationships between landscape attributes and aphid density with the abundance and proportion of native coccinellid (related to exotics) were found at 1000 m from the focal field. Native coccinellids were more abundant in alfalfa when surrounding landscapes had more native shrublands and semi-urban areas than in those with more annual crops. At lower aphid densities, the proportion of native coccinellids was higher in alfalfa when surrounding landscapes had more irregular patches, and lower when landscapes contained more annual crops. Significant effects of landscape attributes and aphids on biological control were found at 1000 m, with better control observed in alfalfa fields in landscapes with more regular patches, when aphid densities were lower, and when surrounding landscapes had more annual crops. Biological control was positively correlated with the abundance of all coccinellids and with exotic species, but not with natives. These results show that landscape composition and heterogeneity affects not only the composition of coccinellids in alfalfa fields but also the efficacy of biological control. Landscapes that favor native species do not necessarily result in better biological control within crops.

Key words: Chile, landscape composition, patch shape, relative abundance, spatial scale

REFUGE FOR NATIVE LADY BEETLES (COLEOPTERA: COCCINELLIDAE) IN PERENNIAL GRASSLAND HABITATS

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Coccinellid communities are increasing in species richness with the intentional or unintentional introduction of exotic species, while simultaneously declining in species evenness as the abundance of native species decreases, potentially due to predation by or competition with these exotic species. The destruction of natural habitats may exacerbate this trend, since invasion success is often tied to environmental degradation. Our objective was to determine whether coccinellid community composition varies between simplified non-native agricultural tall fescue habitats and diverse natural tallgrass prairie habitats, either remnant or restored. We predicted that natural tallgrass prairie habitats would resist the establishment of exotic coccinellid species and promote the abundance and species richness of native coccinellid species as compared to the agricultural tall fescue habitats. We compared coccinellid communities between natural and agricultural habitats by collecting adult coccinellids from five remnant tallgrass prairies, five restored prairies, and four fescue fields throughout the state of Missouri, USA using yellow sticky traps on a monthly basis throughout two growing seasons. We found that native coccinellids were more diverse and abundant than exotic species regardless of grassland habitat type, comprising over 95% of the lady beetle community in both natural prairie habitats and non-native agricultural fescue habitats. Surprisingly, the grassland habitat considered the most disturbed, agriculturally grown exotic tall fescue, had the highest abundance and species richness of native lady beetles. When comparing species composition across habitats, we found that tall fescue also had a unique composition of species as compared to prairie habitats. However, lady beetle communities in remnant and restored tallgrass prairies were indistinguishable, indicating that prairie restoration successfully re-established coccinellid communities. Our data suggest that promoting perennial grasslands, both natural and agricultural, within disturbed landscapes has the potential to enhance native lady beetle populations.

Key words: diversity, restoration, species richness, tallgrass prairie

GENOTYPE MATCHING IN A PARASITOID-HOST GENOTYPIC FOOD WEB: AN APPROACH FOR MEASURING EFFECTS OF ENVIRONMENTAL CHANGE

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Food webs typically quantify interactions between species, whereas evolution operates through the success of alleles within populations of a single species. To bridge this gap, we quantify genotypic interaction networks among individuals of a single specialized parasitoid species and its obligate to cyclically parthenogenetic aphid host along a climatic gradient. As a case study for the kinds of questions genotype food webs could be used to answer, we show that genetically similar parasitoids became more likely to attack genetically similar hosts in warmer sites, i.e., there was network-wide congruence between the within-species shared allelic distance of the parasitoid and that of its host. Narrowing of host-genotype-niche breadth by parasitoids could reduce resilience of the network to changes in host genetic structure or invasion by novel host genotypes and thus inhibit biological control. Our approach can be easily used to detect changes to sub-species-level food webs, which may have important ecological and evolutionary implications, such as promoting host-race specialization or the accelerated loss of functional diversity following extinctions of closely related genotypes.

Key words: climate change, food web, genetic congruence, interaction network, parasitoids

APHID AND NATURAL ENEMIES DENSITIES AND PARASITISM IN RELATION TO LANDSCAPE AND FIELD SCALE COMPLEXITY – MULTISCALE APPROACH

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Many studies have investigated effects of agricultural practices on ecosystem functioning and agrobiodiversity on local (field) and landscape scale. Most of them were focused on a single agroecosystem type. Here, we simultaneously analyzed the relationship between landscape and field scale complexity with respect to aphid and their natural enemies densities and parasitism rate in different agroecosystems with a multi-scale approach. We selected fifteen non-overlapping circular landscapes (1 km diameter) in the vicinity of Smederevo (Serbia), along a landscape complexity gradient ranging from simple (> 80% crop habitats) to complex landscapes (< 20% crop habitats). In each landscape, three fields differing in level of habitat complexity (wheat, alfalfa, old field) were chosen. At both scales, lower habitat complexity generally corresponds with higher management intensity. Sampling was conducted in one season, during the period of peak pest pressure in crop fields. Due to strong correlation among different cover types per landscape we reduced number of possible landscape explanatory variables to a smaller set of uncorrelated variables using Spearman's rank correlation coefficient. Thus, one categorical variable with tree levels (alfalfa, wheat, old field) and percentage of three cover types per landscape: annual crops (including wheat), alfalfa, and habitats composed of trees and shrubs (mainly linear elements) were included in the models as explanatory variables. We tested if simple habitats support higher aphid densities (resource concentration hypothesis), while increase in habitat complexity foster higher parasitism and natural enemies densities (natural enemy hypothesis). Further, we hypothesized that similar pattern exist on a landscape scale, with higher aphid densities in simple agricultural landscapes and higher parasitism rates and natural enemies densities in more complex landscapes. We tested relationships between local density of selected organism groups in different habitats and landscape complexity at different spatial scales (250 m, 500 m and 1 km diameter). The results of this study will be presented and discussed in details.

Key words: agroecology, agricultural complexity, aphids, parasitoids, wheat, alfalfa

DO INEXPERIENCED ANTS (HYMENOPTERA: FORMICIDAE) COLLECTING HONEYDEW RECOGNIZE APHIDOPHAGES DURING THEIR FIRST ENCOUNTER?

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Recognition of aphidophages is a key factor for ants that protect myrmecophilous aphids from their natural enemies. I have tried to understand the role of social and individual experience in this process and determine if there are any differences in behavior between experienced and inexperienced honeydew collectors during their first encounter with aphidophages. Honeydew collectors of *Formica pratensis* Retz. obtained from the field (control) were compared with laboratory-reared 'naïve' ants, which had never met either 'mature' workers, aphids or aphidophages. Observations were made during their interactions with various aphid natural enemies, including imagos and larvae of *Harmonia axyridis* (Pallas) and the lacewing *Chrysotropia ciliata* (Wesmael) and larvae of the hoverfly *Syrphus ribesii* (L.). Naïve ants were significantly more aggressive towards imagos than towards larvae of aphidophages. More than 70% of naïve ants recognized adult ladybirds and lacewings as enemies, attacking them straight away. Naïve ants were significantly more aggressive towards lacewing adults than ants collected from the field. Significant differences were evident only during ant interactions with larvae of aphidophages. The frequency of aggressive reactions (body jerking and bites) towards predator larvae was significantly higher in control ants, whereas naïve ants directed more investigative behaviours toward aphidophages. Overall, experience was not a prerequisite for ants to display key behavioural reactions toward aphidophagous adults (ladybirds and lacewings). However, cumulative experience was inferred to play an important role in the recognition of aphidophagous larvae by ants and the development of aggressive behaviour in honeydew collectors towards these aphid enemies.

The study was funded by the RFBR (13-04-00268).

Key words: ant-aphid-aphidophage interaction, behavior, myrmecophily, predator recognition, trophobiosis

ARE APHIDS A TOOL FOR TRACKING PREDATOR MOVEMENT BETWEEN MAIZE AND ALFALFA USING STABLE ISOTOPE ANALYSIS?

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Knowledge of whether, how and when natural enemies switch between crops can help to delimit the role of crops as reservoirs and open possibilities for landscape management to improve biological control functions. Carbon stable isotope analysis may be used for tracking predator movement because plant signatures remain in the food web and can be traced in herbivores and their predators. This is especially true when C3 and C4 plants are compared because of the distinct ratio of $\delta^{13}\text{C}$ within these plant types. In irrigated areas of the northeastern Iberian peninsula, the agricultural landscape consists mainly of arable crops which share many natural enemies of pests. Alfalfa and maize, which are C3 and C4 plants, respectively, are prevalent crops in spring and summer. Aphids are common in alfalfa and maize; they are crop-specific and preyed upon by both specialist and generalist predators. We hypothesized that aphids could be used as reference herbivores for determining the movement of predators between crops and inferring the role of these crops as predator reservoirs for each other where they coincide. We tested this hypothesis using the polyphagous predator *Orius majusculus* (Heteroptera: Anthocoridae) and the aphidophagous coccinellid *Coccinella septempunctata* (Coleoptera: Coccinellidae) at two points in maize development: at an early vegetative stage in spring (T1), and at a reproductive stage in summer (T2). The hypothesis was confirmed at T2 when aphids were common and predator switching between crops was observed. However, at T1 the hypothesis was not confirmed because aphids on maize were scarce and showed $\delta^{13}\text{C}$ signatures from C3 plants, probably due to migration from winter cereals to maize. At T2, all *C. septempunctata* collected in maize and alfalfa yielded $\delta^{13}\text{C}$ levels corresponding to alfalfa, showing that this crop served as a reservoir of the coccinellid and that it visited maize only occasionally and remained there for only a short time. However, *O. majusculus* collected in maize, and most collected in alfalfa, showed $\delta^{13}\text{C}$ from maize, indicating that maize becomes a source of this polyphagous predator for alfalfa during summer.

Key words: aphids, conservation biological control, *Coccinella septempunctata*, *Orius majusculus*, spillover

SESSION 2

COCCINELLID ECOLOGY

MODERATORS: MICHAUD, J.P. AND NEDVĚD, O.

PARENTAL EFFECTS IN APHIDOPHAGOUS COCCINELLIDAE AND THEIR LIFE HISTORY CONSEQUENCES

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Maternal effects consist of epigenetic mechanisms which mothers can use to modify the phenotypes and life histories of their progeny. Whether such effects are fixed (selection-based) or contingent on particular environmental cues (detection-based) it is generally accepted that they can evolve in response to selection. Over the past two years, considerable evidence has come to light about the significance of both maternal and paternal effects in aphidophagous coccinellids. Here I present data from several species, primarily *Coleomegilla maculata* and *Hippodamia convergens*, to illustrate the range of maternal effects in this group and how they have likely been shaped by selective forces associated with an aphidophagous lifestyle. These include effects on egg size, rate of embryonic development, duration and number of life stages, and final progeny body size. Thus, the progeny of a single female differ not only in their genetics, but also as a function of their sequence of production. Furthermore, by manipulating larval access to food and hence adult body size, a measure of female condition, it is possible to show that maternal signals are costly and that poor maternal condition constrains transgenerational signaling. Although coccinellid females are primarily income-breeders, capital resources accumulated during larval development interact with the adult food supply to shape trajectories of female reproductive effort. There is also evidence that males contribute paternal effects that can influence female fecundity and fertility, progeny survival and progeny developmental rate, but that the strength of paternal signaling, presumably accomplished via allohormones in seminal fluids, diminishes rapidly as a function of sexual activity.

Key words: body size, egg size, development, maternal effects, paternal effects

LADYBIRD FORAGING BEHAVIOUR AN UNDERESTIMATED PROCESS

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A complete understanding of the behavioural and ecological mechanisms underpinning ladybird foraging behaviour is needed to increase their biological control impact in agriculture. Most work on aphids has focused on behaviour related to attack or close contact with their natural enemies. However, predators affect prey populations not only by eating them, but also indirectly through disturbance and avoidance, so-called 'non-consumptive' effects. Ladybirds leave chemical 'footprints' during foraging and these are used by conspecifics to avoid cannibalism and competition. The aim of our research was to investigate whether the bird cherry-oat aphid, *Rhopalosiphum padi* L., could detect the semiochemicals of its predator, the seven spot ladybird, *Coccinella septempunctata* L. The results show that aphids can detect and avoid ladybird chemical tracks and that these can reduce host plant colonization by up to 50%. Aphid avoidance behaviour was dependent on ladybird sex and number of individuals suggesting that aphids use this information to make complex assessments of predation risk. This avoidance mechanism may play an important role in the biological control exerted by predatory ladybirds on aphid populations. Since aphid populations in crops develop exponentially after the arrival of migrants, a decrease in aphid plant acceptance can lead to a significant reduction in aphid numbers, and disturbance by predators can be a major impact on aphid population development. Ladybird immigration into crop fields is not always correlated with aphid abundance. The search for favorable habitats depends on behavioural cues that elicit an intensified search, for example volatiles conveying information on plant status. Our studies showed that increased botanical diversity, e.g., the presence of weeds in a barley field or specific cultivar mixtures, can be significantly more attractive to ladybirds than pure stands of barley, even at low aphid abundance. Thus occurrence of ladybirds early in the growing season depends mainly on growing conditions of the crop or on the cropping system itself. These conditions can potentially be manipulated to the benefit of ladybirds by designing cropping systems which enhance botanical diversity.

Key words: botanical diversity, *Rhopalosiphum padi*, *Coccinella septempunctata*, larval tracks, predator avoidance

EVOLUTION OF SLOW AND FAST DEVELOPMENT IN PREDATORY LADYBIRDS

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It is well documented that coccid eating ladybirds develop more slowly and as a consequence have much lower potential rates of population increase than similar sized aphid eating ladybirds. Analyses of the rate of development of aphid and coccid eating ladybirds at different temperatures indicate that the difference in their rate of development is not due to differences in body size, food quality, lower temperature thresholds for development or a phylogenetic constraint, but in the number of day degrees they require to complete their development, which in the case of coccid eating ladybirds is 3 times greater than that required by similar sized aphid eating ladybirds. In addition to ladybirds there are several other groups of predatory and parasitic insects that attack aphids and coccids. For a better understanding of the marked difference in the pace of life of ladybirds attacking aphids and coccids it is important to know whether other insect natural enemies also show similar differences in their pace of life. If this is the case it will indicate that it is advantageous for coccid eating natural enemies generally to develop and forage more slowly than aphid eating natural enemies. Evidence will be presented that indicates that we are dealing with a general rather than a specific response, as parasitoids, like ladybirds, show similar differences in their pace of life associated with whether they attack aphids or coccids. In addition empirical data will be presented and models used to show that it is advantageous for natural enemies to develop slowly in those cases in which their prey develops slowly, and is relatively uncommon and dispersed in space.

Key words: aphids, coccids, natural enemies, pace of life, parasitoids

MATERNAL INVESTMENT THROUGH SIBLING CANNIBALISM IN THE LADYBIRD BEETLE *HARMONIA AXYRIDIS* (COLEOPTERA: COCCINELLIDAE): THE ROLE OF EGGS SIZE

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Many aphidophagous ladybird beetles lay their eggs in clusters and sibling cannibalism occurs at hatching; early hatchlings will cannibalize all developed and developing eggs in a cluster. Both unhatched and late-developing eggs are a form of maternal investment and may be regarded functionally as trophic eggs. These eggs increase survival rate of cannibal hatchlings. However, the characteristics of the cannibalized eggs have not been well investigated. I investigated egg size and size distribution patterns of hatched and unhatched eggs in *Harmonia axyridis*. Hatching eggs were significantly larger than unhatched eggs and the ratio of unhatched eggs was biased toward smaller ones. These results suggest that the relatively smaller unhatched eggs are a maternal investment in the form of food for the early hatching larvae.

Key words: eclosion, functional trophic egg, hatchling, sibling cannibalism

ASYMMETRIC REPRODUCTIVE INTERFERENCE BETWEEN SPECIALIST AND GENERALIST *HARMONIA* LADYBIRDS IN JAPAN

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Closely related species often differ greatly in the quality and breadth of foods and habitats utilized, but the actual mechanisms causing these differences are poorly understood. In this study, we examined the effect of the interspecific negative mating interactions (reproductive interference) on the niche separation in two *Harmonia* ladybirds in their native range in Japan. *Harmonia axyridis* is a generalist predator with a broad prey and habitat range, whereas *H. yedoensis* is a specialist predator that preys only on highly elusive aphids on pine trees. When adults of the two species were experimentally housed together, mating success decreased substantially in *H. yedoensis* but not in *H. axyridis*. Therefore, it is suggested that asymmetric reproductive interference by *H. axyridis* may force *H. yedoensis* to specialize exclusively on less preferred prey in nature.

Key words: Coccinellidae, niche partitioning

PATERNITY AND SPERM COMPETITION AMONG MALES OF THE LADYBIRD *HARMONIA AXYRIDIS* (COLEOPTERA: COCCINELLIDAE)

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Ladybird beetles are sexually very active and promiscuous, raising questions about the evolutionary importance of multiple matings and mating before overwintering. Our study used eight microsatellite loci to provide the first direct evidence that females of *Harmonia axyridis* are highly polyandrous in the wild and that they not only mate multiple times, but also use sperm from multiple males to fertilize their eggs. Within a single generation in the Czech Republic, both the estimated number of male partners per female, and the effective number of males siring progeny, were about twice as high in the spring sample (5.2 and 3.1, respectively), during the peak reproductive period, than in the preceding autumn sample (2.8 and 1.6, respectively). Values obtained from a spring sample in southern France were lower (2.3 and 1.5, respectively) possibly due to lower population densities at the invasion front. Subsequently, we investigated factors determining realized paternity following multiple female matings. The first male had a paternity advantage over the second male and males of the spectabilis morph had paternity advantage over males of the axyridis morph. Analysis of paternity using microsatellites, which avoids possible biases due to differential mortality of progeny, confirmed first male precedence and the higher paternity rate of colour morphs that are more frequently observed in the wild. The study explains why male ladybirds mate so frequently, do not guard females, differences in frequency of colour morphs, and how this alien invasive ladybird can maintain high genetic variability while colonizing new areas.

Key words: fertilization, overwintering, polyandry, promiscuity, reproduction

AGE-SPECIFIC MATERNAL EFFECTS INTERACT WITH LARVAL FOOD SUPPLY TO MODULATE LIFE HISTORY IN *COLEOMEGILLA MACULATA* (COLEOPTERA: COCCINELLIDAE)

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Maternal effects can modify progeny phenotypes to improve their survival under variable conditions, such as changes in food supply. In aphidophagous coccinellids, maternal effects can influence egg size, developmental rate, and final adult body size. Four cohorts of *C. maculata* larvae were reared from four different points in their mothers' reproductive lives (1st, 12th, 24th and 36th oviposition days) and divided into two diet treatments for rearing; 30 min daily access to eggs of *Ephestia kuehniella* or ad libitum. Progeny survival was lower on restricted food but increased over the first 12 oviposition days in both treatments, suggesting mothers did not conform to the theoretical norm of producing their 'best' progeny first. Larval development was delayed on the restricted diet, but there was no effect of oviposition day on total developmental time, although pupation was faster in the final cohort than in the first. The restricted diet amplified a developmental polymorphism evident in both treatments, increasing the percentage of larvae that added or subtracted an instar. The results suggest that mothers employ a mixed strategy and produce subsets of progeny that either adopt an 'optimistic' or 'pessimistic' strategy when facing food limitation; namely, undergo an additional instar to take advantage of any late improvement in the food supply, or forgo an instar and the associated costs of the molt to pupate at a small size, respectively. A larger percentage of later cohorts pupated after only three instars in both treatments, suggesting that a larger proportion of later-hatching progeny are maternally programmed for pessimism, as would be adaptive for larvae exploiting aphid populations in decline.

Key words: developmental polymorphism, egg size, fecundity, food limitation, reproduction

FIRST EVIDENCE OF A VOLATILE SEX PHEROMONE IN THE INVASIVE *HARMONIA AXYRIDIS* PALLAS (COLEOPTERA: COCCINELLIDAE)

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Until now, volatile sex pheromones have not been identified in the Coccinellidae, although various studies have suggested the existence of such molecules. We have sampled volatile organic compounds released in the headspace of virgin females of the multicolored Asian ladybeetle, *Harmonia axyridis* Pallas, that were either allowed or not to feed on pea aphids, *Acyrtosiphon pisum* Harris. When fed aphids, virgin females showed a stereotypical ‘calling behavior’ associated with the emission of a sex pheromone in several Coleoptera species. Behavioral assays conducted with calling females in a four-arm olfactometer demonstrated that the blend of released volatile compounds was attractive for males, but not for other females. The headspace of virgin females that were not previously fed on aphids was not attractive for either sex. GC-MS analyses revealed the presence of five compounds in the volatile blend: (–)-β-caryophyllene, β elemene, methyl-eugenol, α-humulene and α-bulnesene. Subsequently, we collected and quantified the constituents from the blend over a period of nine days after exposure to aphids. All five compounds were produced exclusively after feeding virgin females with aphids, and their quantity significantly increased over the period of collection. (–)-β-caryophyllene was found to be the major constituent, representing between 80 and 89 % of the total blend. These results could promote the development of more specific and efficient management methods to manipulate the movements of this invasive ladybeetle and to reduce its negative impacts on biodiversity.

Key words: female calling behavior, multicolored Asian ladybeetle, olfactometry, (–)-β-caryophyllene

IDENTIFICATION OF PREY ITEMS IN FRASS OF THREE LADYBIRD BEETLES LIVING ON BLACK ALDER

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In the colder regions of the north temperate zone, most predatory ladybird beetles feed mainly on aphids and use other food sources as alternative prey. However, stenotopic species that occur on black alder trees are considered by some to specialize on other prey types: *Calvia quindecimguttata* on chrysomelid larvae and *Sospita vigintiguttata* on psyllids. Food preferences can be characterized using molecular techniques which are now well-developed. Alternatively, frass analysis is a simple and direct observational method often neglected by researchers as being too inaccurate and tedious. We studied prey remains in the frass of three species of ladybirds living on black alder, *C. quatuordecimguttata*, a generalist species, and two specialists, *S. vigintiguttata* and *C. quindecimguttata*. The remains of preys detected in frass were compared with potential prey collected on black alder, allowing us to identify food items with an accuracy ranging from order to species. We found that *C. quindecimguttata* and *S. vigintiguttata* are not as specialised as generally assumed, since they mainly consumed the aphid *Pterocallis alni*, along with many other types of prey. All three species seemed to prey opportunistically upon Psocoptera, Psyllidae, Auchenorrhyncha, eggs of Coleoptera and mites. Though frass dissection has a limited accuracy, we propose combining this approach with stable isotope analysis for a quantitative description of ladybird beetlefood sources. We present here preliminary results of this combined approach.

Key words: *Alnus glutinosa*, *Calvia quindecimguttata*, *Calvia quatuordecimguttata*, diet breadth, frass analysis, *Sospita vigintiguttata*

EFFECTS OF ALTERNATIVE PREY ON LARVAL DEVELOPMENT AND REPRODUCTION OF THE LADY BEETLE *CHEILOMENES SEXMACULATA* (COLEOPTERA: COCCINELLIDAE)

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Eggs of the Angoumois grain moth, *Sitotroga cerealella*, honey and honeydew have been tested as foods for the lady beetle *Cheilomenes sexmaculata*. Our laboratory population of *C. sexmaculata* originated from insects collected in Nepal (Sauraha, 27°34'29" N, 84°29'37" E) in May, 2013. Adult and larvae were maintained in laboratory condition (27±2°C, 18L:6D day length) using the greenbug, *Schizaphis graminum*, as the control diet. When larvae fed on *Sitotroga* eggs with honey, fresh adult body weight was not reduced compared to controls. Females weighed 10.8-11.2 mg and males 8.0-8.4 mg. However, the survival rate was only 20% compared to 77% in controls. Cannibalism was considered to be one of the main reasons for high mortality of larvae. *Sitotroga* eggs with honey represent a suitable diet only for development of larval instars 3-4, which had about 80% survival. Rearing on *Sitotroga* eggs increased the pre-oviposition period to 21 days and dramatically decreased fecundity. Dissections of 30 day-old adults showed that the alternative food induced reproductive diapause in 87% of females. We then provided *Sitotroga* eggs together with leaves of *Tilia cordata* bearing honeydew of the line aphid, *Eucallipterus tiliae* to try and stimulate oviposition. We hypothesized that honeydew could be a cue for termination of diapause in females, with *Sitotroga* eggs serving as the nutrient source for vitellogenesis. In nature, the aphid colony would combine both the cue and the nutrients for oviposition. When adults fed on *Sitotroga* eggs and honeydew, only 4.5% of females had a preoviposition period similar to controls (3-4 days). So the tested population contained a small number of females for which *Sitotroga* eggs and honeydew were sufficient to break diapause and induce oogenesis, but most females needed other stimuli before oviposition. We discuss some advantages of intraspecific heterogeneity in regulation of reproductive diapause in predatory coccinellids.

Key words: honeydew, oviposition, reproductive diapause, *Sitotroga cerealella*

THE EFFECT OF VERMICOMPOST ON POPULATION GROWTH PARAMETERS AND FECUNDITY OF *HIPPODAMIA VARIEGATA* (GOEZE) FEEDING ON *APHIS GOSSYPYII* (HEMIPTERA: APHIDIDAE)

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The melon aphid, *Aphis gossypii* Glover is a major pest of greenhouse plants, particularly cucumbers. The ladybird beetle *Hippodamia variegata* (Goeze) is an aphidophagous predator with worldwide distribution. This study evaluated the effects of different vermicompost concentrations (0, 15 and 30 %) on population growth parameters of *H. variegata*. The experiments were carried out in a growth chamber at 25 ± 2 °C, $65 \pm 10\%$ RH and 16L:8D photoperiod. Our results revealed that immature developmental time, fecundity and adult female longevity of *H. variegata* fed on *A. gossypii* did not vary significantly whether the aphids were reared on cucumber plants grown in 0, 15 and 30% vermicompost media. However, life table parameters such as r_m were significantly affected by soil amended with vermicompost. The longest values (0.152 d⁻¹) and lowest values of r_m (0.120 d⁻¹) were observed in the 30% and 0% vermicompost treatments, respectively. The results showed that vermicompost does not have negative effects on the life table parameter or fecundity of *H. variegata*, so the strategy of using vermicompost in combination with *H. variegata* may be useful for controlling the melon aphid in cucumber greenhouses.

Key words: Coccinellidae, development, life table, organic fertilizer, reproduction

CONTRASTING POPULATION GROWTH PARAMETERS OF THE APHIDOPHAGOUS *SCYMNUS NUBILUS* AND THE COCCIDOPHAGOUS *NEPHUS REUNIONI* (COLEOPTERA: COCCINELLIDAE)

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Compared to coccidophagous ladybirds, aphidophagous ladybirds develop and live faster. They also produce more eggs at a faster rate. We determined population growth parameters for the aphidophagous *Scymnus nubilus* Mulsant (Coleoptera: Coccinellidae) and the coccidophagous *Nephus reunioni* Fürsch (Coleoptera: Coccinellidae) fed *Rhopalosiphum padi* (L.) (Hemiptera: Aphidoidea) and *Planococcus citri* (Risso) (Hemiptera: Coccoidea), respectively, under controlled laboratory conditions. Net reproductive rate, intrinsic rate of natural increase, and finite rate of increase were all significantly higher, and generation time and doubling time were both significantly shorter in *S. nubilus* compared to *N. reunioni*. Reproductive output of the aphidophagous species rapidly reached a peak and then sharply declined, whereas that of the coccidophagous predator was more evenly distributed throughout adult life. A significant difference in late survival was found, with *S. nubilus* exhibiting higher survival. Adaptation to the consumption of aphids and coccids occurred in several species during the co-evolutionary history of ladybird beetles and their prey. Comparisons of other species would be valuable to confirm the differences reported here.

Key words: development, *Planococcus citri*, population parameters, *Rhopalosiphum padi*, reproduction

SESSION 3

APHID PARASITIDS

MODERATORS: KAVALLIERATOS, N.G. AND VORBURGER, C.

SYMBIONT-CONFERRED RESISTANCE TO PARASITOIDS – IMPLICATIONS FOR BIOLOGICAL CONTROL

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Only ten years ago the first paper was published demonstrating that heritable bacterial endosymbionts can protect aphids against parasitoids. An explosion of research since then has shown that symbiont-conferred resistance is widespread in insects in general, and in aphids in particular. This challenges existing theory on host-parasitoid interactions. Using models that incorporate effects of symbionts, we identify several factors that are important in determining the dynamics of host-parasitoid coevolution when mediated by symbionts, such as the specificity of symbiont-conferred protection, the costs associated with harboring symbionts, and their rate of horizontal transmission. We are in the process of studying these factors empirically in a model system comprising the black bean aphid, *Aphis fabae*, its defensive symbiont, *Hamiltonella defensa*, and the parasitoid *Lysiphlebus fabarum* (Hymenoptera: Braconidae). The results so far indicate that symbionts play a crucial role in altering the reciprocal selection process between hosts and parasitoids, leading to coevolutionary dynamics that are not observed in their absence. I discuss implications of these findings for biological control of pest aphids with parasitoids.

Key words: coevolution, cost of resistance, *Hamiltonella defensa*, *Lysiphlebus fabarum*, symbiosis

THE ROLE OF HOST AND HOST-PLANT PHYLOGENIES IN APHID PARASITOID SPECIFICITY

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We explore the hypothesis that aphid phylogenetic placement and the phylogenetic placement of the plant hosts of these aphids have an influence on patterns of specificity. We report results from specificity experiments done on three aphidiine braconid parasitoids - *Binodoxys communis*, *Lysiphlebus testaceipes* and *Lipolexis* sp. For each parasitoid species, females were exposed to aphids belonging to approximately 20 aphid species on various host plant species, and parasitoid mummification levels, emergence rates and sex ratios were scored. These data were then mapped onto phylogenies of both the aphids and their host plants to evaluate phylogenetic signal for parasitism traits. We found different patterns for the three parasitoid species tested. For *B. communis*, which is a specialist parasitoid, we found a strong signal of host but not host-plant phylogeny. For *L. testaceipes*, which is a generalist, we found no signal of either host or host-plant phylogeny. For *Lipolexis* sp., however, we found no signal of host phylogeny but a signal of plant phylogeny as this parasitoid specializes on aphids attacking grasses. These studies expose the variability in host-specificity patterns of aphid parasitoids and we discuss possible ecological determinants of such variability as well as implications for biological control.

Key words: *Binodoxys communis*, host specificity, *Lysiphlebus testaceipes*, *Lipolexis* sp.

RELATIONSHIP BETWEEN APHID TRAITS AND GENERALIST-SPECIALIST HOST-USE OF PARASITOIDS

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Host specificity is a fundamental properties of parasitoids. Parasitoids with narrow host ranges (high specificity) tend to be more efficient in their resource-use compared to generalists. This pattern is documented in aphid parasitoids and can be explained by the trade-off hypothesis between host range breadth and host use efficiency. However, it remains largely unknown how a variety of host-related factors, such as host susceptibility to parasitoids, influence the generalist-specialist trade-off. In this study we identified the most important aphid traits influencing the relationship between host specificity and abundance on the shared host by analyzing data from a 13-year survey of interactions among 142 aphid and 75 parasitoid species in nine European countries. Our results indicate that aphid species which form sparse colonies support a higher proportion of specialist parasitoids compared to those which form dense colonies. Furthermore, the effect of additional aphid traits on the generalist-specialist trade-off, such as honeydew production, myrmecophily and exposure of colonies, was more pronounced when the taxonomic relationship among hosts was considered in calculating parasitoid host ranges. We conclude that host traits influence the generalist-specialist trade-off, especially so when host specificity is measured as host taxonomic distance. The ecological implications are discussed as well as the potential and limitations of the approach.

Key words: host specificity, aphid parasitoids, resource use efficiency, generalist-specialist trade-off, taxonomic distance

PARASITOIDS (HYMENOPTERA: BRACONIDAE: APHIDIINAE) OF APHIDS INFESTING HERBACEOUS AND SHRUBBY ORNAMENTAL PLANTS IN SOUTHEASTERN EUROPE

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Collections of both live and mummified aphids from ornamental herbs and shrubs were made between 1975–2011 from numerous sites (i.e., parks, roads, avenues, gardens) in Bulgaria, Croatia, Greece, Montenegro, Serbia and Turkey. One hundred nineteen aphidiine-aphid-herbaceous and 147 aphidiine-aphid-shrubby (total 266 aphidiine-aphid-plant) associations were identified. The associations include 22 aphidiine species belonging to the genera *Aphidius*, *Binodoxys*, *Diaeretiella*, *Ephedrus*, *Lipolexis*, *Lysiphlebus* and *Praon*. The aphidiines were reared from 40 aphid taxa on 105 plant taxa (48 herbaceous and 57 shrubby). One hundred twenty six of the associations were previously undocumented. New associations are reported for the following parasitoid species: *Aphidius asteris* Haliday (1), *Aphidius colemani* Viereck (14), *Aphidius matricariae* Haliday (34), *Aphidius rosae* Haliday (1), *Aphidius urticae* Haliday (1), *Binodoxys acalephae* (Marshall) (1), *Binodoxys angelicae* (Haliday) (18), *Diaeretiella rapae* (M'Intosh) (5), *Lipolexis gracilis* Förster (1), *Lysiphlebus confusus* Tremblay and Eady (3), *Lysiphlebus fabarum* (Marshall) (12), *Lysiphlebus testaceipes* (Cresson) (3) and *Praon volucre* (Haliday) (33). Information about the host range and distribution of aphidiines attacking aphids feeding on ornamental herbaceous and shrubby plants in southeastern Europe is provided. The study reveals that several species are economically important parasitoids of aphids (i.e., *A. colemani*, *A. matricariae*, *A. urticae*, *B. angelicae*, *D. rapae*, *E. persicae*, *E. plagiator*, *L. fabarum*, *L. testaceipes*, *P. volucre*). *A. colemani*, *B. angelicae* and *L. testaceipes* heavily parasitized certain aphid species in the region. A potential range expansion of *L. testaceipes* from coastal to continental areas of southeastern Europe into cooler climatic conditions was also recorded.

Key words: aphids, distribution, host plants, tritrophic associations

THE FLEXIBLE RESPONSES TO PLANT ODOUR OF A GENERALIST APHID PARASITOID, *APHIDIUS COLEMANI* (HYMENOPTERA: BRACONIDAE)

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Adult parasitoids of aphids encounter chemical cues which influence their olfactory preferences as they emerge firstly through the cuticle of the pupa, then the cocoon around the pupa, and finally the cuticle of the aphid mummy. In an olfactometer, *Aphidius colemani* parasitizing the aphid *Myzus persicae* reared on Brussels sprout plants show strong preference for the odour of the specific cultivar on which they develop. However, there also appears to be an innate preference for the odour of plants in general over clean air. The chemical cues in the mummy cuticle can be eliminated by rearing *M. persicae* on a fully-defined artificial diet with no secondary chemistry. The presumed innate response to general plant volatiles persists, but *A. colemani* then show no discrimination between sprout cultivars. As previous work has shown, at oviposition the mother parasitoid leaves a chemical cue to the host plant on which she developed which is too weak to influence the olfactory behaviour of the emerging parasitoid, but is revealed if the emerged parasitoid is allowed to contact the exterior of a mummy from either the maternal cultivar of origin or a different cultivar. To eliminate also the maternal influence, the *A. colemani*/*M. persicae* culture on artificial diet was continued to a second generation. Only the innate response to plant odour over clean air remains. If the parasitoid pupa is excised from the mummy, emerging parasitoids still show the olfactory preference for the cultivar of origin, suggesting diffusion of plant cues within the mummy to the cuticle of the parasitoid pupa. However, this preference can be blocked by contact with one mummy from a different sprout cultivar. Laboratory experiments with potted plants and *A. colemani*, either emerged from the mummy or from excised pupae, showed that the above odour responses affect the percentage of *M. persicae* parasitized.

Key words: *Brassica* cultivars, mummy, olfaction, volatiles

ADAPTIVE EVOLUTION OF A GENERALIST PARASITOID: IMPLICATIONS FOR THE EFFECTIVENESS OF BIOLOGICAL CONTROL AGENTS

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The use of alternative hosts imposes divergent selection pressures on parasitoid populations. In response to selective pressures, these populations may follow different evolutionary trajectories. Divergent natural selection could promote local host adaptation in populations, translating into direct benefits for biological control by increasing their parasitoid effectiveness on the target host. Alternatively, adaptive phenotypic plasticity could be favored over adaptive genetic differentiation in temporally and spatially heterogeneous environments. We investigated the existence of local host adaptation in *Aphidius ervi* (Hymenoptera: Braconidae), an important biological control agent, by examining different traits related to infectivity (preference) and virulence (a proxy of parasitoid fitness) on different aphid-host species. The results showed significant differences in parasitoid infectivity on natal hosts compared with non-natal hosts. However, parasitoids showed similarly high virulence on both natal and non-natal hosts, supporting a lack of host adaptation in these introduced parasitoid populations. Our results highlight the role of phenotypic plasticity in fitness-related traits of parasitoids that enable them to maximize fitness on alternative hosts and could be used to increase the effectiveness of biological control. In addition, *A. ervi* females showed significant differences in infectivity and virulence across the tested host range, suggesting a possible host phylogeny effect on those traits.

Key words: *Aphidius ervi*, divergent selection, infectivity, phenotypic plasticity, virulence

PARASITISM THRESHOLD FOR EFFECTIVE BIOLOGICAL CONTROL OF CEREAL APHIDS IN DIFFERENT LANDSCAPE TYPES

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The aphid-parasitoid complex in wheat agroecosystems has often been used as a model system for assessing the impacts of landscape properties on diverse ecosystem processes and services. Surprisingly, few studies have quantified the level of parasitism required to result in effective biological control. A four year study (2008-2011) of cereal aphids in winter wheat near Belgrade, Serbia, investigated the ecosystem services provided by parasitoids in agricultural landscapes. We compared three structurally contrasting landscape types: simple (predominantly large crop fields); compositionally heterogeneous (a high proportion of non-crop land), and configurationally heterogeneous (predominantly small crop-fields). The parasitism threshold required for successful biological control was defined as that yielding zero or negative aphid population growth between wheat flowering and ripening (milk stage). The effects of parasitism rate on aphid population growth were tested with linear regression with data pooled across years for each of the three landscape types, and pooled for the whole study. In simple, large-field landscapes, zero growth threshold was obtained with a parasitism rate of 26% ($F_{1,59} = 19.93$, $P < 0.001$). In compositionally heterogeneous landscapes, the threshold was 25% ($F_{1,22} = 6.99$, $P = 0.01$), whereas in small-field landscapes, the threshold was only 18% ($F_{1,9} = 5.44$, $P = 0.04$). When data was pooled across both years and all landscapes, the parasitism threshold was 25% ($F_{1,94} = 33.7$, $P < 0.001$). We conclude that parasitism threshold for effective biological control in cereal aphid-parasitoid complex ranges from 18-26%, presumably closer to the 25% mark, since the 18% value approached marginal significance of effects, probably due to small sample size of small field landscapes ($n = 12$ vs. $n = 25$ for the other two types). These parasitism thresholds are above values recently published by Thies et al. (2011) (~15%), but much lower than the frequently cited 32–36% range established by Hawkins and Cornell (1994). Moreover, despite the variability in other landscape-mediated effects in this system (Plećaš et al. in press), we noted that parasitism rate was consistently associated with effective biological control of cereal aphids.

Key words: agroecology, landscape ecology, parasitoids

EMERGENCE OF APHID PARASITOIDS (HYMENOPTERA: BRACONIDAE AND APHELINIDAE) AT LOW TEMPERATURE

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Aphid parasitoids are widely used in Europe for aphid control in protected crops. However, there is some reluctance to use them during winter. There is indeed a common belief that those insects will not emerge during this period. We monitored temperature and parasitoid emergence in an unheated tunnel, an unheated greenhouse (temperature kept above 0 °C) and a heated greenhouse (temperature kept above 10 °C) between January and April. We used a mix of six species (*Aphidius colemani*, *A. ervi*, *A. matricariae*, *Aphelinus abdominalis*, *Praon volucre*, *Ephedrus cerasicola*) called FresaProtect. FresaProtect is a cardboard tube containing the mummies of those parasitoids. In common conditions, at least 240 individuals emerge. In the heated greenhouse, where temperature was between 10 and 15 °C, 240 adults had emerged within two weeks after installation of the tubes. In the cold greenhouse, the coldest conditions were between week 2 and week 6 with a mean daily minimum temperature of 1 °C and a daily maximum between 12 and 14 °C. In these conditions, emergence started two weeks after installation of the tubes and reached a normal number of adults after four weeks. In the tunnel, the first tubes experienced extremely low night temperature (around -10 ° for two weeks). Those tubes yielded 50 to 60 emerging adults, mainly belonging to the genus *Aphidius*. The tubes installed later in the season were also subject to negative nighttime temperatures, however, not as cold and of shorter duration than the first. In this case, emergence started one week after installation and reached a maximum of 251 emerging adults. In conclusion, prolonged periods alternating between extremely cold temperatures during night and positive temperatures during the day can cause mortality but do not completely stop emergence. However, in contrast to the common belief that those insects will not emerge at low temperature and during the short day period, we demonstrated that, under common winter conditions for a plastic tunnel in temperate climate (temperature around 0°C at night and between 5 and 20°C during the day), no mortality was recorded and the expected number of adults emerged, however, with a small delay with respect to the heated greenhouse.

Key words: aphid, biological control, winter

STUDY ON SOME BIOLOGICAL PARAMETERS OF *PAUESIA ANTENNATA* MUKERJI (HYMENOPTERA: BRACONIDAE, APHIDIINAE), A PARASITOID OF *PTEROCHLOROIDES PERSICAE* (HEMIPTERA: APHIDIDAE: LACHNINAE)

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Brown peach aphid, *Pterochloroides persicae* (Cholodkovsky), is one of the serious and destructive pests of many prunaceous fruit trees in the Palaearctic. *Pauesia antennata* Mukerji (Hymenoptera: Braconidae, Aphidiinae), a specific parasitoid of *P. persicae*, has recently been introduced in Tunisia. We determine the effect of host population density on biological parameters of *P. antennata*. Parasitoids were introduced to three different densities ($n = 3$ per density) of *P. persicae* ($D1 < 50$, $50 < D2 < 100$, $100 < D3 < 150$) reared on peach shoots in KNOP solution under laboratory conditions ($21 \pm 4^\circ\text{C}$, $\text{RH} = 70\%$). Means of developmental time, adult lifespan, female fecundity, and emergence rate all varied with host density. The fastest development was at D2 (15.34 ± 1.08 d) compared to D1 and D3 (13.31 ± 1.01 and 14.81 ± 1.88 d, respectively). Moreover, parasitoid longevity was greater on D2. Although the highest female fecundity was obtained at D3 (37.16 ± 26.67), emergence was higher on D1 (0.40 ± 0.21).

Key words: developmental time, fecundity, host density, longevity

CAN APHID ALARM PHEROMONES INDUCE CHANGES IN CONSPECIFIC APHID REPRODUCTIVE RATES?

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Aphids respond to attack by predators and parasitoids through both direct defensive behaviors and by alerting conspecifics with alarm pheromones. These alarm pheromones have been shown to induce defensive behaviors in aphids with no direct exposure to natural enemies. We hypothesized that these alarm pheromones may also induce changes in aphid reproductive rates. Prior experiments with soybean aphid, *Aphis glycines* (Hemiptera: Aphididae), revealed a form of reproductive overcompensation in response to parasitism by *Lysiphlebus orientalis* (Hymenoptera: Braconidae). However, preliminary modeling suggests this overcompensation is insufficient to explain the high aphid densities observed in the face of high parasitism rates in cage studies. Reproduction by aphids near, but not in direct contact with, aphids under attack by *L. orientalis* will be reported and discussed.

Key words: *Aphis glycines*, compensation, fecundity, *Lysiphlebus orientalis*

TEMPERATURE AND HOST PLANT EFFECTS ON DEMOGRAPHIC PARAMETERS OF *APHIDIUS TRANSCASPICUS* TELENGA (HYMENOPTERA: BRACONIDAE)

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Aphidius transcaspicus Telenga (Hymenoptera: Braconidae) is a solitary endoparasitoid, and a synovogenic koinobiont with arrhenotokous reproduction. This wasp is a specific parasitoid of the *Hyalopterus pruni* species complex (Hemiptera: Aphididae). The pest attacks trees of the genus *Prunus* such as almond, apricot and peach. In order to determine the effects of temperature and host plant on the performance of the mealy plum aphid parasitoid *A. transcaspicus*, we used no-choice tests and we measured demographic parameters such as longevity, parasitism rate, emergence rate and sex-ratio under controlled conditions. The experiments were conducted with two host plants, *Phragmites communis* and *Prunus amygdalinus* (almond), and at four different temperatures (20, 23, 25 and 27 °C). The experiments showed that the shortest adult longevity occurred at 27 °C (3 ± 1 d) and the longest at 20 °C (9.6 ± 6 d), both on *P. communis*. However, the highest emergence rate (74%) was observed on almond at 20 °C. The sex-ratio was female-biased on both plant hosts and independent of temperature. We conclude that the best temperature is 27°C on almond which yielded 6 ± 1 d longevity, 55% parasitism, and 69% parasitoid emergence with a sex ratio of 0.6\ (male/female).

Key words: parasitism rate, emergence rate, sex-ratio, longevity

SESSION 4

IPM AND BIOLOGICAL CONTROL OF APHIDS

MODERATOR: BRODEUR, J.

THE SCREENING OF BIOCONTROL AGENTS TO CONTROL APHIDS IN GREENHOUSES

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Aphids are difficult to control in protected crops, especially in sweet pepper, where *Myzus persicae*, *Myzus persicae nicotianae* and *Aulacorthum solani* are key pests. An overview is presented of research that screened parasitoids (Hymenoptera), lacewings (Neuroptera: Chrysopidae) and plant bugs (Hemiptera: Miridae) for their potential as biocontrol agents. The testing process proceeded from petri dishes to small cages, larger cages, and finally field applications. Many candidate species failed this process, but a few are now commercialized or remain under further investigation in the research program. Most field trials were done in eco-greenhouses. The results also indicate how these beneficial species can influence each other and how to apply them in a proper and timely manner.

Key words: *Aphidius colemani*, *Aphidius matricariae*, *Chrysoperla lucasina*, *Dicyphus errans*, *Macrolophus pygmeus*

EFFECTS OF TEMPERATURE AND WATER ACTIVITY ON MYCELIAL GROWTH OF NINE TUNISIAN ENTOMOPATHOGENIC FUNGAL ISOLATES AS BIOCONTROL AGENTS AGAINST THE ARTICHOKE APHID *CAPITOPHORUS ELAEAGNI* DEL GUERCIO (HEMIPTERA: APHIDIDAE)

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An understanding of the effects of abiotic variables on the infectivity of insect-pathogenic fungi is essential to predict their usefulness in the field and to develop them as microbial control agents. Temperature and water activity, key factors determining the environmental competence of entomopathogenic fungi, were evaluated on nine Tunisian soil isolates that were previously molecularly characterized. These belonged to 6 taxa: *Beauveria*, *Bionectria*, *Lecanicillium*, *Metacordyceps*, *Metarhizium*, and *Isaria* that had been already examined as potential microbial control agents of the artichoke aphid, *Capitophorus elaeagni* Del Guercio (Hemiptera: Aphididae). Laboratory experiments to evaluate colony growth rates were carried out over eight days at two-day intervals, in a range of 15-35 °C, with optimum temperature for germination and growth ranging from 22.5 to 30.9 °C. All isolates were able to grow up to 36 °C; however, only *Bionectria ochroleuca*, *Metacordyceps liangshanensis* and *Paecilomyces marquandii* tolerated temperatures up to 38 °C. The effect of water activity effect on the above parameters was evaluated over nine osmotic potentials (ψ = 0 to 200 bars) by changing the glycerol concentration in the culture media at 25 °C. The colony growth of all isolates was highest from 0 to 20 bars and no isolates grew above 100 bars. Increasing the osmotic potential decreased the rate of mycelial growth by 0.2 to 0.3 mm per day in all isolates. This study demonstrated that the tested isolates could be considered as potentially good microbial control candidates in the semi-arid and arid Tunisian bioclimatic conditions.

Key words: colony growth, environmental competence, osmotic potential

RISK AND EFFICACY IN BIOLOGICAL CONTROL: THE INTRODUCTION OF *APHELINUS CERTUS* (HYMENOPTERA: APHELINIDAE) IN NORTH AMERICA

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Importation (“classical”) biological control entails risks to non-target species as well as the potential benefit of target pest suppression. Typically, prior to release of a classical biological control agent (BCA), host range tests are performed to predict non-target risk and generalist BCAs are precluded from release. Little is known, however, how host range may impact efficacy of BCAs in controlling target pests. The parasitoid *Aphelinus certus* (Hymenoptera: Aphelinidae) was considered for release against the invasive soybean aphid, *Aphis glycines* (Hemiptera: Aphididae), in North America. Broad parasitism by *A. certus* within Aphididae indicated a high risk to native aphids and it was deemed too risky to release. However, *A. certus* was inadvertently introduced and first recorded in Pennsylvania, USA in 2005. It has since been found throughout much of the North American soybean growing region. Interestingly, this accidental introduction presents an opportunity to explore the interaction between risk and efficacy of a BCA. We designed a field experiment to explore the direct and indirect effects of *A. certus* on the target soybean aphid and on non-target grain aphids. Implications for risk-benefit analysis in biological control are discussed.

Key words: *Aphis glycines*, apparent competition, invasive species, non-target effects, parasitoid

CROP ASSOCIATION TO IMPROVE BIOLOGICAL CONTROL: A CASE STUDY ON PEA AND WHEAT APHIDS

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Nowadays, strategies used to control aphids in fields of pea, *Pisum sativum* L., and wheat, *Triticum aestivum* L., still rely on synthetic insecticides which have negative effects on the environment and human health. This research focused on the development of sustainable alternative methods, with special emphasis on cultural practices and plant management systems. Increasing the diversity within crops may have several beneficial effects on pest control, creating attractive habitats for indigenous beneficial fauna and simultaneously deterring pests – the ‘push-pull’ approach. In this field study, two wheat/pea associations (mixed cropping and strip cropping) were compared to monocultures of pea and wheat. The abundance and diversity of adult aphidophagous insects (predators and parasitoids) were assessed weekly using yellow traps, while aphids were observed directly on plants. In both crops, the percentage of plants infested with aphids and density of aphid colonies were significantly higher in monocultures during periods of aphid abundance. Mixed cropping was particularly beneficial for the pea, whereas strip-cropping was more efficient for the wheat. The abundance of beneficials was significantly higher in monocultures comparing to the other treatments. Quantitative aphid-natural enemy food webs showed that the abundance of the two main ladybird species, *Coccinella septempunctata* L. and *Propylea quatuordecimpunctata* (L.), increased with the occurrence of *Acyrtosiphon pisum* (Harris) on pea plants. Abundance of the two main species of Syrphidae, *Sphaerophoria scripta* (L.) and *Eupeodes corollae* (F.), increased with the occurrence of *Sitobion avenae* (F.) and *Metopolophium dirhodum* (Walker) on wheat plants. This study shows that increasing diversity within crops can help lower aphid infestations. However, additional methods are needed to more efficiently attract aphidophagous beneficials and promote the natural control of aphids.

Key words: Coccinellidae, mixed cropping, monocultures, strip cropping, Syrphidae

IMPACT OF NATURAL ENEMIES ON WHEAT AND COTTON APHIDS IN NORTHERN CHINA

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Aphids are a major pest in wheat-cotton rotations in the North China plain. Aphids in wheat and cotton fields are currently managed with broad-spectrum insecticides, which is unsustainable because of the negative impacts on natural enemies and insecticide resistance in the aphids. Therefore, it is crucial to identify key natural enemies of aphid pests on wheat and cotton and optimize conservation biological control in these crops. A field survey of wheat aphid, *Sitobion avenae*, and cotton aphid, *Aphis gossypii*, and their natural enemies was conducted during two growing seasons, 2010-2011 and 2011-2012, at Langfang Experimental Station of IPP-CAAS, south-east of Beijing. In wheat, populations of *S. avenae* peaked at 23 ± 1.6 aphids per tiller on May 23, 2011 and 50 ± 3.6 aphids per tiller on May 17, 2012. In cotton, *A. gossypii* populations peaked at 138 ± 8.8 aphids per plant on July 24, 2011 and 3193 ± 23.5 aphids per plant on July 16, 2012. When all natural enemies were excluded with small-mesh cages, *S. avenae* peaked 2-fold higher (2011-2012) and 41-fold higher (2011) compared to large-mesh cages (exclusion of large predators only, e.g., coccinellids) and 7-fold higher than in uncaged plants. Populations of *A. gossypii* peaked 1.5-fold (2011) and 2-fold higher (2012) in small-mesh cages than in large-mesh cages and 2-fold (2011) and 8-fold higher (2012) compared to uncaged plants. These results confirmed that the main aphid natural enemies in wheat were parasitoids, in particular *Aphidius gifuensis*, whereas in cotton, *A. gifuensis* was important in early plant growth stages, and Coccinellidae and Anthocoridae in later growth stages. In addition, we observed some predatory coccinellids in wheat and some Chrysopidae and spiders in cotton. Further studies will assess the side effects of pesticides on *A. gifuensis* and coccinellids to aid in incorporating their biocontrol services into an integrated pest management strategy for wheat and cotton.

Key words: *Aphidius gifuensis*, *Aphis gossypii*, Coccinellidae, natural enemy exclusion, *Sitobion avenae*

POSTER PRESENTATIONS
ABSTRACTS

WHY TWO SPECIES OF SOYBEAN APHID PARASITOIDS SHOWED PROMISE IN THE LABORATORY BUT FAILED UNDER FIELD CONDITIONS

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Following the rapid spread of the soybean aphid, *Aphis glycines*, in North America in the early 2000's, biological control was selected as a cost-effective approach for management of soybean aphid populations. Two parasitoid species, *Binodoxys communis* and *Aphidius colemani* were considered promising candidates for classical and inundative biological control programs, respectively. The present study assessed the overwintering capacity of *B. communis* under the climatic conditions prevailing in Québec, Canada, and measured parasitism and dispersal capacity of *A. colemani* when released in soybean fields. Field and laboratory assessments revealed that the Chinese *B. communis* strain we tested had very poor diapause capability (< 0.8%) and was thus unlikely to establish in northern North America. *Aphidius colemani* did not show strong potential to control *A. glycines*. Following the release of approximately 8400 females, only 113 mummies were recovered within a radius of 60 m from the release point. Although both species appeared promising under controlled conditions, the Chinese *B. communis* strain and the *A. colemani* commercial strain did not show strong potential to control *A. glycines* populations in Quebec soybean fields.

Key words: *Aphis glycines*, *Aphidius colemani*, *Binodoxys communis*, biological control, dispersal

HARMONIA AXYRIDIS IN RUSSIA

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The natural habitat of *Harmonia axyridis* is the Russian Far East, southern Siberia and the Altai Mountains. Two subspecies live in the area, the boundary between them is located near Lake Baikal. Western and eastern subspecies differ in the most common elytral patterns. We also found the specific mitotype among beetles of western subspecies not found in the east. In 2010, *H. axyridis* appeared in Kaliningrad, in the western region of Russia. In 2012, a few individuals were found in the Belgorod district on the border with Ukraine. Since *H. axyridis* already had occupies Ukraine and Latvia, we can expect its appearance in the European part of Russia in the near future.

Key words: distribution, subspecies

MORPHOLOGICAL TRAITS OF THE FOREWING IN THREE *ADIALYTUS* SPECIES (HYMENOPTERA: BRACONIDAE) WITH MOLECULAR ANALYSIS OF MTCOI GENE

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Adialytus Foerster 1862 is a small genus of parasitic wasps within the subfamily Aphidiinae (Braconidae). So far, seven valid species of the genus have been recognized: *A. ambiguus* (Haliday), *A. balticus* Starý and Rakauskas, *A. fuscicornis* (Ashmead), *A. kaszabi* Takada, *A. salicaphis* (Fitch), *A. thelaxis* (Starý) and *A. veronicaecola* (Starý). This study examines the three most common species of *Adialytus* in Europe: *A. ambiguus*, *A. salicaphis* and *A. thelaxis*. *A. ambiguus* parasitizes aphids from the genus *Sipha* on Poaceae, whereas *A. salicaphis* attacks species of the genus *Chaitophorus*, many of which are pests on poplars and willows. *A. thelaxis* is restricted to aphids of the genus *Thelaxes* on oak trees. All three species are morphologically quite similar and difficult to distinguish. Geometric morphometrics of forewing size and shape along with molecular analysis of mitochondrial gene cytochrome oxidase I (COI) were used in tandem to resolve morphological differences between the species and see if those differences were supported at the molecular level. Results of the forewing size and shape analysis revealed statistically significant differences. *A. ambiguus* and *A. salicaphis* differed mostly in the length of the metacarpal vein, the former having a much longer metacarpus. The morphology of *A. thelaxis* forewing is similar to that of *A. salicaphis* in metacarpal length, but *A. thelaxis* has a slightly broader wing, especially in its distal part. Molecular analysis of COI gene was mostly concordant with the geometric morphometrics. *A. thelaxis* was clearly separated from the other two species and formed a separate clade in the phylogenetic tree. *A. ambiguus* and *A. salicaphis* were much closer to each other according to genetic analysis, with an average genetic distance of 1.1% between them. However, they still form two separate clades in the phylogenetic tree.

Key words: *Adialytus*, parasitoids, geometric morphometrics

APHIDIUS AND EUAPHIDIUS (HYMENOPTERA: BRACONIDAE: APHIDIINAE): TAXONOMIC STATUS AND PHYLOGENETIC RELATIONSHIP

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The Aphidiinae (Hymenoptera: Braconidae) are small solitary endoparasitoids of aphids. A member of this subfamily, *Euaphidius cingulatus* (Ruthe 1859) parasitizes only aphids of the genus *Pterocomma* Buckton on willows and poplars, whereas *Euaphidius setiger* (Mackauer 1961) parasitizes only aphids from genus *Periphyllus* van der Hoeven on maples. In addition, *Remaudierea plocamaphidis* Starý 1973 parasitizes aphids from genus *Plocamaphis* Oestlund on *Salix* spp. We employed the mitochondrial gene cytochrome oxidase I (COI) barcoding area to analyze the phylogenetic relationship among *E. cingulatus*, *E. setiger* and *R. plocamaphidis*. Furthermore, we examined the morphological variability of *E. cingulatus* and *E. setiger* using geometric morphometric analysis. Finally, the taxonomic status of all species in relation to the genus *Aphidius* Nees 1818 was explored. Molecular analysis showed that *E. setiger* formed clade together with species from the genus *Aphidius*, suggesting that this species probably belongs to the genus *Aphidius*. On the other hand, *R. plocamaphidis* and *E. cingulatus* clustered into two close clades, indicating that these two species are representatives of different genera. The geometric morphometric analysis of forewing size and shape showed significant differences between *E. cingulatus* and *E. setiger*. The wing of *E. cingulatus* is elongated and narrow in the central area and has a shorter metacarpus, whereas the *E. setiger* wing is shorter and broader in the central area with a longer metacarpus.

Key words: mitochondrial COI gene, geometric morphometrics

LONG-TERM EFFECTS OF MASS REARING ON THE PERFORMANCE OF *COCCINELLA UNDECIMPUNCTATA* (COLEOPTERA: COCCINELLIDAE)

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Coccinella undecimpunctata L. is an aphidophagous predator with potential to be used as a biocontrol agent in augmentation programs. However, it is generally accepted that mass rearing biocontrol agents for extended periods in laboratory conditions may result in a decrease in the performance. We have tested the biological performance of *C. undecimpunctata* kept in the laboratory for approximately one year under controlled physical conditions (25 °C, 75% RH, and 16L:8D photoperiod) and fed with a mixed diet of *Aphis fabae* and *Myzus persicae*. Performance was then compared on single diets of *A. fabae* and *M. persicae* at four different temperatures (15, 20, 25 and 30 °C). Immature survival was extremely low at 15 and 30 °C, independent of prey species. At 20 and 25 °C, immature survival was high (70%) on *M. persicae* and quite low on *A. fabae* (30%). At 20°C, the sex ratio was male biased on *M. persicae*, but female-biased on *A. fabae*. At 25 °C, the sex ratios were more or less balanced. The reproductive parameters of *C. undecimpunctata* were generally better on *M. persicae*, regardless of temperature. Our results suggest that continuous rearing of *C. undecimpunctata* under constant temperatures limits its ability to cope with extreme temperatures (e.g., 15 and 30 °C). *Aphis fabae* seems to be a low quality prey for this ladybird, whereas *M. persicae* is more suitable.

Key words: *Aphis fabae*, biological control, ladybird, *M. persicae*, temperature

**BIOLOGY OF *SCYMNUS SUBVILLOSUS* (GOEZE)
(COLEOPTERA: COCCINELLIDAE) FED ON *MELANAPHIS
DONACIS* (PASSERINI)**

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Scymnus subvillosus (Goeze) is an aphidophagous predator present in the Azores of Portugal. It occurs at low densities and has recently been observed exploiting *Melanaphis donacis* (Passerini) on *Arundo donax* L. *Scymnus* spp., although less studied than other genera, have been the subject of research as possible biological control agents in recent years. The development of *S. subvillosus* was studied under a 16L:8D photoperiod and 75±5% RH at four constant temperatures: 15, 20, 25 and 30 °C; reproduction was studied at 25 °C under similar conditions. Development time from larvae to adult decreased with temperature, ranging from 62.8 days at 15 °C to 10.7 days at 30 °C. Maximum juvenile survival was obtained at 20 °C (85.7%) and minimum survival was recorded at 15 °C (30.8%). Development from larvae to adult required 192.8 DD (degree-days) above a base of 11.6 °C, the estimated lower developmental threshold. At 25 °C, the preoviposition period was 7.5 days. Total fecundity over 20 days of reproduction was 152.8 eggs, a rate of about 8 eggs per day. Egg fertility was high with 94.4% of eggs hatching. The results obtained suggest that *M. donacis* is a suitable prey for *S. subvillosus*.

Key words: development, lower development threshold, reproduction, fertility

COSTS AND BENEFITS OF WAX PRODUCTION IN LARVAE OF *SCYMNUS NUBILUS* MULSANT (COLEOPTERA: COCCINELLIDAE)

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Larvae of the aphidophagous *Scymnus nubilus* Mulsant (Coleoptera: Coccinellidae) are covered by a wax layer that might act as a defensive mechanism against natural enemies. However, the costs of wax production and the benefits of protection conferred by the wax remain to be assessed. In this study we tested two hypotheses: 1) wax production is associated with detrimental physiological (growth, reproduction) or behavioral costs (behavioral compensation); and 2) wax production is an effective defense against intraguild predation. Tests were carried out in the laboratory with waxy and waxless larvae and lacewing larvae were used as putative intraguild predators. The results confirmed both hypotheses at least partially. Adults derived from waxy larvae were heavier than those derived from waxless larvae, but no difference was found in their reproductive potential. Biomass consumption was similar in waxy and waxless larvae, but body-weight gain and conversion efficiency were higher in the former. As expected, wax reduced the rate of intraguild predation by lacewing larvae. These results clearly indicate the existence of a trade-off between larval growth and the protection afforded by wax production.

Key words: development, ladybird, intraguild predation, trade-off

BARCODING THE GENUS *EPHEDRUS* HALIDAY (HYMENOPTERA: BRACONIDAE)

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The genus *Ephedrus* Haliday (Hymenoptera: Braconidae: Aphidiinae) is considered as basal within the subfamily due to many plesiomorphic characters (i.e., forewing with seven closed cells, 11 antennal segments in males and females, black mummies, emergence hole with a cap in the apical portion of the mummy). This is confirmed by comparative molecular findings. Three species groups are recognized within the genus: “*persicae*”, “*plagiator*” and “*lacertosus*”. We used sequence information from the barcoding region of the mitochondrial cytochrome oxidase subunit I (mtCOI) gene in order to characterize *Ephedrus* species and analyze relationships between species groups. Two different phylogenetical methods (maximum parsimony and maximum likelihood) yielded very similar results and the existence of three similar groups was confirmed. Surprisingly, big genetic distances (> 20%) were found between the *persicae* group and the other two. Large genetic distance was found also among genera in the subfamily Aphidiinae; at least two species new to science were discovered.

Key words: cytochrome oxidase subunit I, parasitoid, phylogeny

VARIABILITY IN SEXUAL SIZE DIMORPHISM IN THREE SPECIES OF PREDATORY LADYBIRDS: WHICH SEX IS MORE SENSITIVE TO ENVIRONMENTAL FACTORS?

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We compared patterns of allometry in sexual size dimorphism (SSD) under the influence of several factors (temperature, food etc.) in three species of predatory ladybirds of similar size: *Propylea dissecta*, *Cheilomenes sexmaculata* and *Cryptolaemus montrouzieri*. The greenbug, *Schizaphis graminum*, eggs of the Angoumois grain moth, *Sitotroga cerealella*, and honey were provided as food. To estimate the adaptive potential of species we measured adult weight in diapause on less 10 mg, including under environmental stress, when survival was decreasing. Reduced major axis regression (RMA) was used to quantitatively describe the relations between female and male size, because RMA is more appropriate when the independent variable is measured with error. As expected, increasing temperature decreased adult body size in both sexes of all species. However, the degree of SSD was either stable or strongly variable among species. When phenotypic plasticity was induced in *C. sexmaculata* by high temperature, SSD increased with decreasing body size, the regression line yielding a negative intercept (coefficient $b_2 < 0$ in model $y = x \cdot b_1 + b_2$). Therefore male size is more sensitive to temperature conditions than female. Conversely, in *P. dissecta* the regression line had a positive intercept; SSD declined (by a factor of 1.4) with decreasing female body size (from 10.7 mg to 7.8 mg). In this case, female size changed relatively faster than male size, corresponding to Rensch's rule for female-biased SSD. In *C. montrouzieri*, the intercept was close to zero, which implied a proportional decrease in male and female size with increasing temperature or food deprivation. SSD was stable (1.10-1.12). Thus, in *C. sexmaculata* and *C. montrouzieri* temperature-induced variation in adult weight did not conform to Rensch's rule, suggesting that these species might have an adaptive advantage under conditions of increasing temperature. The discovered patterns of allometry in SSD are discussed in connection to morphometry of the reproductive system and female body size. We discuss some potential explanations for these patterns based on different adaptive strategies in these species.

Key words: adult size, *Cheilomenes sexmaculata*, *Cryptolaemus montrouzieri*, *Propylea dissecta*, Rensch's rule

DETECTION OF PREDATION BY *HARMONIA AXYRIDIS* (COLEOPTERA: COCCINELLIDAE) UNDER FIELD CONDITION USING POLYMERASE CHAIN REACTION

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Despite their role in pest suppression, exotic generalist predators can, under certain conditions, negatively impact non-target communities. The invasive beetle *Harmonia axyridis* has become one of the dominant coccinellid species in regions where it has become established. Although intraguild predation (IGP) by *H. axyridis* has been implicated as the primary cause for displacement of several native species of ladybird beetles, field quantification of IGP is lacking in most systems. Using molecular gut-content analysis, we characterized the trophic relationship between *H. axyridis*, two native coccinellids, *Adalia bipunctata* and *Oenopia conglobata*, and an extraguild prey, the aphid *Eucallipterus tiliae*. Species-specific 16S primers were developed for the three potential prey species and laboratory feeding trials were conducted to quantify the rate of prey DNA breakdown in the gut of *H. axyridis*. Fourth-instar *H. axyridis* were systematically collected from linden trees in northern Italy and screened for the presence of prey DNA. Sixty-five percent of larvae preyed upon aphids until early July, after which predation decreased to 43%, in parallel with declines in aphid populations. The frequency of aphid prey detection was positively correlated with prey availability. Intraguild predation was relatively low; 1.5% and 5% of *H. axyridis* larvae screened positive for *A. bipunctata* and *O. conglobata* DNA, respectively), but represented a potentially significant trophic pathway and intraguild effect. Results suggest that *H. axyridis* larvae may contribute to *E. tiliae* suppression due to high predation frequencies, but some negative effects on native coccinellids may occur. These results elucidate the role of *H. axyridis* in biological control of aphids in invaded ecosystems, and its effectiveness in pest suppression versus its potential negative impact on predatory species of the same trophic level.

Key words: intraguild interactions, invasive species, molecular gut-content analysis

MUTUAL INTERFERENCE AMONG APHIDOPHAGOUS COCCINELLIDS

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Mutual interference involves direct interactions between individuals of the same species that may alter their foraging success. Larvae of aphidiphagous coccinellids typically stay within a patch during their life, displaying remarkable aggregation to their prey. A study was initiated in order to determine the effect of mutual interference on coccinellid feeding rates. One to four fourth instar larvae of the fourteen-spotted ladybird, *Propylea quatuordecimpunctata* L. (Coleoptera: Coccinellidae), were exposed for six hours in plastic containers with different densities of the black bean aphid, *Aphis fabae* Scopoli (Hemiptera: Aphididae), on potted *Vicia faba* L. plants. Data were fitted to Crowley-Martin model within a Bayesian framework. Attack rates were significantly lower at a density of four larvae compared to other tested densities, although predator density did not affect the coccinellid's handling time. In addition, the magnitude of interference was not affected by predator density. Our laboratory study suggests that mutual interference does not affect the feeding rate of coccinellid larvae at high prey densities, whereas at low prey densities it is affected at a critical predator density. It is inferred that the time spent during digestion breaks at high prey densities fully accommodates the cost of interference.

Key words: attack rate, handling time, competition, feeding rate

TRITROPHIC INTERACTIONS AMONG APHIDS AND PRIMARY AND SECONDARY PARASITIDS IN SLOVENIA

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In the period 2006-2012, 40 species of Aphidiinae parasitoids belonging to 11 genera were found in Slovenia. 175 interactions among aphids, primary and secondary parasitoids were recorded, in which 50 aphid species were parasitized by 40 primary parasitoids and associated with 17 secondary parasitoid species. In 2008, a review of aphid fauna in Slovenia counted 197 species. We found 13 species from 8 genera that are new to this country. An overview of secondary parasitoid presence and association with various agroecosystems and natural ecosystems in Slovenia are reported for the first time. The number of interactions was highest for *Sitobion avenae*, which was associated with six primary and 12 secondary parasitoids. Three species of secondary parasitoids were found only in cereal agroecosystems, i.e., *Alloxysta brachyptera*, *Dendrocerus aphidus* and *Pachyneuron muscarum*. A high number of primary parasitoids was found on *Hyalopterus pruni* and *Acyrtosiphon pisum*. Associations of secondary parasitoids with the aphid *Staticobium limonii* and a primary parasitoid new to science, *Aphidius staticobii*, are also recorded for the first time.

Key words: Aphidiinae, trophic interactions, hyperparasitoids

THE KILLER LADYBIRD

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Male-killing is one of four known strategies that inherited parasitic endosymbionts have evolved to manipulate their host reproduction. Ladybird beetles are particularly susceptible to invasion by various species of male-killing bacteria. These bacteria, which are maternally inherited, cause the death of male host embryos. The ladybird *Harmonia axyridis* has recently been categorized as an invasive alien species (IAS). Although it is an efficient biocontrol agent of aphids, *H. axyridis* has also turned out to be major threat to native species of ladybirds and many non-target aphids. There is a great interest in developing measures to control *H. axyridis* populations. Male-killing is argued to affect the fitness of infected populations, in which there can be a very strongly female-biased sex ratio. It is argued that male-killing endosymbionts may then be used for biocontrol of invasive *H. axyridis*.

Key words: endosymbionts, inherited bacteria, male-killing, sex ratio distortion

QUALITATIVE ANALYSIS OF APHID-HYPERPARASITOID TROPHIC RELATIONS OF GENUS *ALLOXYSTA* (HYMENOPTERA: CYNIPOIDEA: FIGITIDAE: CHARIPINAE)

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Species of the genus *Alloxysta* (Hymenoptera: Cynipoidea: Figitidae: Charipinae) are aphid hyperparasitoids (Hemiptera: Aphididae) via Aphidiinae (Hymenoptera: Braconidae) and Aphelininae (Hymenoptera: Aphelinidae). Charipines impact the effectiveness of the primary parasitoids by decreasing their abundance and modifying their behavior, sometimes resulting in increasing of aphid populations and economic crop losses. The host specificity of these hyperparasitoids is still a matter of debate. According to Evenhuis, the majority of the Charipinae species are specialists on certain aphid/primary parasitoid combinations, whereas Fergusson treats them mainly as generalists. Here we give an overview of the trophic relationships between Charipinae species and their aphid/primary parasitoids hosts worldwide, from Mexico to Iran and Spain through central Europe. Within this subfamily, *Alloxysta arcuata*, *A. brevis* and *A. victrix* are the most generalist species, sharing most of their hosts. *Alloxysta darci* and *A. citripes* appear to be the most specialist species. Primary parasitoid genera *Aphidius*, *Lysiphlebus*, *Praon* and *Trioxys* are the most common hosts for *Alloxysta* species, usually in aphids of genera *Aphis*, *Uroleucon*, *Myzus* and *Sitobium*. Host range is analysed for each *Alloxysta* species, and the extent of overlap between them. The Jaccard index, used to determine host range dissimilarity, is given using a cluster analysis. The level of specificity of each *Alloxysta* species is evaluated with different indices.

Key words: Aphelinidae, Braconidae, distribution, host range

LONG TERM MASS REARING DOES NOT DECREASE THE FITNESS OF *SCYMNUS NUBILUS* (COLEOPTERA: COCCINELLIDAE).

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The Azorean ladybird community is dominated, in terms of abundance, by Scymnini species, particularly *Scymnus nubilus* and *S. interruptus*. Nevertheless these aphidophagous predators are poorly studied. Under an augmentative biological control strategy, natural enemies of agricultural pests are mass-reared for release in crop fields. The present study evaluated the effects of long term laboratory mass-rearing on the performance of *S. nubilus*. Fresh individuals from the field were collected for the 'new' population, whereas individuals of the 'old' population were kept for a year under controlled laboratory conditions ($25 \pm 1^\circ \text{C}$, $75 \pm 5\% \text{RH}$, 16:8/L:D photoperiod, fed on a mixed diet of *Aphis fabae* and *Myzus persicae*). Three treatment groups from each population were fed monotypic diets of *A. fabae*, *Melanaphis donacis* or *M. persicae*. Development time and immature survival were determined and newly emerged adults were paired for reproduction so that pre-oviposition period, fecundity and fitness could be calculated. There was a significant interaction between prey species and colony age on development time, with differences at both levels. No significant interaction between prey species and colony age was found for pre-oviposition, fecundity and fitness. The pre-oviposition period was independent of prey species and predator age, whereas fecundity was dependent on prey species. The number of eggs laid did not differ between diets of *A. fabae* and *M. donacis* but significantly fewer eggs on *M. persicae*. Fitness was dependent on both prey species and colony age, the old population presenting higher fitness. The predator had significantly lower fitness on *M. persicae* than on *A. fabae* or *M. donacis*. It is generally accepted that mass rearing has detrimental effects on the performance of biological control agents. However for *S. nubilus* at 25°C , mass rearing apparently did not decrease fitness, but rather it improved it significantly on *A. fabae*. Our results suggest that *M. persicae* is a lower quality prey for *S. nubilus*, whereas *A. fabae* and *M. donacis* seem equally suitable.

Key words: *Aphis fabae*, biological control, *Melanaphis donacis*, *Myzus persicae*, Scymnini

THE DEGREE OF PROTECTION DIFFERENT ANTS (HYMENOPTERA: FORMICIDAE) PROVIDE APHIDS (HEMIPTERA: APHIDIDAE) AGAINST APHIDOPHAGES

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Aphids play an important role in the life of many ants, supplying them with energy-rich carbohydrate food and in exchange for some degree of protection from their natural enemies. This study focused on the degree of protection different ants provide myrmecophilous aphids in multispecies ant communities. Field investigations were carried out in steppe and forest plant associations in Siberia. The aggression level of six ant species (*Formica rufa*, *F. pratensis*, *Lasius fuliginosus*, *L. niger*, *Camponotus saxatilis* and *Myrmica rubra*) towards imagos and larvae of ladybirds and lacewings and larvae of hoverflies was tested in the laboratory. A comparative analysis of the occurrence of aphidophages in colonies of the aphid *Chaitophorus populeti* Panz. and all aphid-symbionts tended by ants (potentially general resources) showed that the degree of protection from aphid natural enemies offered by ants differs significantly among ant species and is positively correlated with ant colony size. The percentage of aphid colonies with aphidophages tended by dominant ants with large and protected foraging territories (*Formica* (s. str.) and *L. fuliginosus*) was about 1.5-3.5 times lower than that for the ants *Lasius* and *Camponotus*. Ants with partially protected territories offered a level of protection about 4-6 times lower than ants with small colonies and non-defended foraging sites. Overall, the degree of protection from aphidophages of myrmecophilous aphids depends both on the aggression level of the ants and their foraging strategy when collecting honeydew (degree of specialisation among honeydew collectors). The dominant ants, *Formica* (s. str.), provided aphids with the highest degree of protection from aphidophages due to their most aggressive behaviour and high level of specialization (clear division of labor in protection of aphids, collection and transportation of honeydew).

Key words: ant-aphid-aphidophage interaction, behavior, *Chaitophorus populeti*, predator protection, trophobiosis

RELATIONSHIP BETWEEN INSECTICIDAL SEED TREATMENTS AND NATURAL ENEMIES OF THE SOYBEAN APHID, *APHIS* *GLYCINES* (HEMIPTERA: APHIDIDAE)

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The use of insecticidal seed treatments is becoming increasingly common on field crops in the United States, though the ecological consequences of such widespread use are not well-understood. This study examines the relationship between thiamethoxam seed treatment in soybean and the abundance and composition of soybean aphid natural enemies found in treated soybeans, compared to untreated soybeans, and soybeans managed with other approaches.

Key words: thiamethoxam, Coccinellidae, Syrphidae, Anthocoridae

THE MULTICOLOURED ASIAN LADYBIRD (COLEOPTERA: COCCINELLIDAE): INVASIVE OR NOT IN AGROECOSYSTEMS?

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The Multicoloured Asian Ladybird, *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae) is known to thrive principally in shrubby and arboreal habitats. Its occurrence in agroecosystems remains poorly documented. The abundance of adults and larvae of *H. axyridis* was evaluated over a four-year period, from 2009 to 2012, in four important agronomic crops (wheat, corn, broad bean and potato) in Belgium. A total of 28 aphid predator species were observed, including 14 coccinellid species, 13 hoverfly species and one lacewing species. *H. axyridis* was present and reproduced in all of the four crops studied, with the largest numbers recorded in corn and broad bean. In corn, *H. axyridis* numbers increased over the four year period, reaching 86% of aphid predators in 2012, whereas it represented only 15% in 2009. *H. axyridis* was not always recorded where aphids were abundant, e.g., aphids were abundant on wheat where no *H. axyridis* were recorded. *H. axyridis* started reproducing after the peak in aphid populations, suggesting that it is able to complete its development by feeding on alternative prey such as larvae and pupae of the same and other species of ladybird and other aphidophagous species. *H. axyridis* is often considered to be bivoltine, but it only completes one generation annually in field crops; the second generation generally develops late in the season in other habitats. *H. axyridis* is an invasive intraguild predator present in high numbers in some specific crops where it could negatively impact populations of native species due to IGP, as observed in other studies.

Key words: abundance, agroecosystems, aphidophagous species, invasive species, intraguild predation

HARMONIA AXYRIDIS (COLEOPTERA: COCCINELLIDAE): CURRENT AND POTENTIAL DISTRIBUTION OF THIS NEW INVADER IN CHILE

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Harmonia axyridis (Pallas) (Coleoptera: Coccinellidae), the multicolored Asian lady beetle or harlequin ladybird, is a generalist predator native to central and eastern Asia that has been introduced to several countries in Europe, Africa, North and South America. After its introduction, this insect has spread rapidly and increased in abundance, becoming a pest in many areas. Today it is considered one of the most serious invasive alien species around the globe, posing a threat to non-target arthropods, affecting fruit production, and becoming a nuisance to humans by overwintering in houses. In Chile in 1998, a flightless strain was introduced from France to central Chile for biological control in greenhouses, but these populations did not establish. The first wild populations were found in 2003, with no subsequent reports until 2008. Since 2008, they have increased significantly in abundance and distribution. In 2012, *H. axyridis* covered a north-south range of ~ 400 km which expanded to ~ 1000 km in 2013. Now, *H. axyridis* is the second or third most abundant coccinellid in alfalfa fields in central Chile, and is very common entering buildings in the fall. Genetic analyses indicate that Chilean *H. axyridis* originate from populations in the northeastern USA, similar to all other introductions in South America and several countries in Europe. Through regional comparisons (Asia vs USA; Asia vs Chile and USA vs Chile), we constructed potential distribution models and niche analysis using MAXENT and bioclimatic variables (worldclim.org; spatial resolution: 10 km), and PCA. We demonstrated a niche shift of invasive populations in the USA in relation to the native ones. The models predicted that *H. axyridis* will increase its distribution southward in Chile. In summary, *H. axyridis* is already established in Chile, but is still in the early stages of invasion, with the potential to increase both its distribution and its abundance.

Key words: alien invasive species, distribution, harlequin ladybird, niche models

APHID PARASITIDS (HYMENOPTERA, BRACONIDAE, APHIDIINAE) OF ALGERIA: DIVERSITY, HOST ASSOCIATIONS AND DISTRIBUTION

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This study presents the results of a survey of aphid parasitoids of the subfamily Aphidiinae (Hymenoptera: Braconidae) in Algeria. Thirty species of aphid parasitoids belonging to nine genera were collected and identified in association with 70 aphid species occurring on 130 host plants. In all, 300 parasitoid-aphid associations were recorded, 29 of which are new to Algeria. The majority of these species were collected on the steppe plants specific to the Saharian Atlas where many endemic plants harbor very specific and uncommon aphid species. All aphid parasitoids reported as new to Algeria and North Africa were found in this transition area (Batna, Biskra and Khenchela regions). The genus *Aphidius* was the most represented. The species *Lysiphlebus testaceipes*, *Aphidius matricariae* and *Aphidius ervi* were the most common.

Key words: *Aphidius*, *Lysiphlebus testaceipes*, Saharian Atlas, North Africa

INTERACTIONS BETWEEN TWO APHID SPECIES ON AFRICAN EGGPLANT, SORREL AND AMARANTH

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Aphids (Homoptera: Aphididae) are polyphagous insects which can be found on several crops in temperate zones, as well as in the tropics. The multiplication of *Aphis gossypii* Glover (C9 cucumber, Burk cotton and Pipo pepper strains) and *Myzus persicae* Sulzer was studied in the laboratory on three plant species: African eggplant, *Solanum aethiopicum*, sorrel, *Hibiscus sabdariffa*, and amaranth, *Amaranthus* spp. Periodic counts were carried out to monitor population growth. The multiplication rate of *M. persicae* was higher than that of *A. gossypii* when these two species were present together on eggplant. Amaranth was less suitable for the development of both species, but *M. persicae* again had a better multiplication rate than *A. gossypii*. This study illustrated the importance of considering not only one pest species, but the whole herbivore guild, especially when biological control is important.

Key words: *Aphis gossypii*, *Myzus persicae*, multiplication rate

THREAT OF INTRAGUILD PREDATION BY THE PREDATORY HOVERFLY *EPISYRPHUS BALTEATUS* DEGEER (DIPTERA: SYRPHIDAE) ON THE APHID PARASITOID *APHIDIUS ERVI* HALIDAY (HYMENOPTERA: BRACONIDAE)

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Intraguild interactions between natural enemies can be an important factor influencing the overall efficiency of biological control. The mechanisms that govern such interactions are not well understood. Here, a range of experiments were conducted to determine whether the predatory hoverfly *Episyrphus balteatus* DeGeer (Diptera: Syrphidae) poses an intraguild threat to the parasitoid *Aphidius ervi* Haliday (Hymenoptera: Aphidiinae), and to discover whether *A. ervi* female can avoid IGP by responding to chemical tracks deposited by *E. balteatus* larvae. Although *E. balteatus* larvae did not consume parasitoid mummies, they did consume parasitized aphids leading to a negative impact on parasitoid population development. Secondly, *A. ervi* females avoided aphid patches where *E. balteatus* larvae were present and similar avoidance was observed to aphid patches with *E. balteatus* larval tracks. Total *A. ervi* parasitism was reduced on *Myzus persicae* Sulzer (Hemiptera: Aphididae) infested *Vicia faba* L with *E. balteatus* larvae or their tracks compared to aphid-infested bean plants without syrphid larvae or tracks. It was concluded that *A. ervi* responds to chemical cues associated with hoverfly predators and defends against the risk of intraguild predation by avoiding oviposition in the presence of *E. balteatus* larvae or larval tracks.

Key words: oviposition avoidance, chemical tracks, *Myzus persicae*, intraguild predation

SEASONAL ABUNDANCE OF APHIDS (HEMIPTERA, APHIDIDAE) AND THEIR PREDATORS (COLEOPTERA, COCCINELLIDAE) ON ALFALFA CROPS IN SERBIA

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Alfalfa aphids are one of the major problems in alfalfa in Serbia, causing severe economic damage. Occurrence and population dynamics of alfalfa aphids and their coccinellid predators were investigated in two insecticide-free alfalfa fields in Ovča-South Banat (young crop) and Progar-Srem (old crop), from April – October, 2011 and March – October, 2012. Samples were taken every ten days at both locations; aphids and predators were collected directly from plant stems ($n = 10$) in each of 20 (Ovča) and 16 (Progar) one m^2 plots. We recorded three aphid species, *Acyrtosiphon pisum* (Harris), *Therioaphis trifolii* (Monell), *Aphis craccivora* Koch and seven aphidophagous coccinellids: *Coccinella septempunctata* L., *Harmonia axyridis* (Pallas), *Hippodamia apicalis* Wse, *Hippodamia heideni* Wse, *Hippodamia variegata* Goeze, *Hippodamia tredecimpunctata* (L.) and *Propylea quatuordecimpunctata* (L.). A total of 9889 aphids and 758 coccinellids were observed. In both localities and years, the most abundance aphid species was *T. trifolii* followed by *A. pisum*, with *A. craccivora* present at lower densities. *C. septempunctata*, *H. variegata* and the invasive *H. axyridis* were the most abundant coccinellids. There was a significant effect of crop on the number of aphids, but no effect of year. There was no effect of crops on the number of predators, but the effect of year was significant. We calculated Pearson's product-moment correlation between numbers of aphids and numbers of predators for each year separately and for both together. Pearson's product-moment correlation between the numbers of aphids and predators was 0.479 for 2011 and 0.628 for 2012, both significantly different from zero. When data for 2011 and 2012 were pooled, Pearson's product-moment correlation was 0.623, also significantly different from zero.

Key words: *Acyrtosiphon pisum*, *Aphis craccivora*, *Therioaphis trifolii*

THE EFFECTS OF LANDSCAPE COMPLEXITY AND AGRICULTURAL INTENSIFICATION ON CEREAL APHID PARASITOIDS

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Biological control of pests in arable fields is an important ecosystem service provided by high-diversity landscapes and species-rich communities. High agricultural intensification and simplification of landscape structure should impair the effectiveness of this control. We investigated how primary parasitoids and hyperparasitoids of aphids are affected by the local landscape structure and agricultural intensity. We hypothesized that: (1) landscape heterogeneity and lower agricultural intensification (AI) will promote an increase in abundance and species diversity of aphid parasitoids; (2) this increased diversity will lead to increased parasitism rates by each group of parasitoids and; (3) more structurally complex landscapes and lower AI will enhance colonization of crops mostly by polyphagous primary parasitoids (e.g., *Praon* sp., *Ephedrus* sp.) and mummy parasitoids. We found no relation between landscape complexity and abundance and diversity of primary parasitoids, but we recorded their higher diversity on less intensively managed fields. Moreover, we found no links between parasitism rate of aphids and landscape complexity and agricultural intensification. Similarly, no effects of AI or landscape complexity were observed on diversity of hyperparasitoids or their effectiveness in parasitizing primary parasitoids. However, we recorded higher numbers of hyperparasitoids in fields with lower AI. Mummy parasitoids were also more abundant in less intensively managed fields and were more diverse in more complex landscapes. Parasitization rates of primary parasitoids by mummy parasitoids were significantly higher in low AI and more complex landscapes

Key words: Aphidiinae, cereals, *Ephedrus* sp., hyperparasitoids, *Praon* sp.

APHIDOPHAGOUS INSECT AND MITES IN ALFALFA FARMS IN HAMEDAN, WESTERN IRAN

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Alfalfa is a perennial plant that is native to Hamedan, west of Iran, where it has been cultivated for longer than any other forage crop. Not only does alfalfa have very high yield potential, but it is also one of the most palatable and nutritious forages. Because of its high protein and vitamin content, alfalfa is a primary component in the diet of dairy cattle, beef cattle and horses. Among the main herbivores in this crop are aphids: *Aphis craccivora* Koch, *Acyrtosiphon kondoi* Shinji, *Acyrtosiphum pisum* Harris and *Therioaphis maculata* Buckton. However, their populations are not economic due to the presence of predatory mites and insects, 15 species of which were observed to be aphidophagous: *Coccinella septempunctata* (L.), *Hippodamia variegata* (Goeze), *Propylea quatuordecimpunctata* (L.), *Psyllobora vigintiduopunctata* (L.), *Coccinella undecimpunctata* (L.), *Chilocorus bipustulatus* (L.), *Exochomus nigromaculatus* (Goeze), *Hyperaspis polita* Weise and *Scymnus flavicollis* Redtenbacher (Coleoptera: Coccinellidae), *Nabis ferus* L. (Hemiptera: Nabidae), *Deraeocoris pallens* L. (Hemiptera: Myridae), *Anthocoris confusus* Reut. (Hemiptera: Anthocoridae), *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae), *Anystis baccarum* L. (Acarina: Anystidae), *Propioseius messor* (Wainstein) (Acarina: Phytoseiidae) and *Cunaxa* sp. Among these, *H. variegata*, *D. pallens*, *A. confusus*, and *A. baccarum* were most abundant and contributed to a natural equilibrium of aphids in the alfalfa.

Key words: aphid predators, *Aphis craccivora*, *Acyrtosiphon kondoi*, *Acyrtosiphum pisum*, *Therioaphis maculata*

EFFECTS OF THREE DIFFERENT DIETS ON BIOLOGY AND GROWTH PARAMETERS OF *HARMONIA AXYRIDIS* (PALLAS) (COLEOPTERA: COCCINELLIDAE)

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The development, survivorship and reproduction of the ladybird *Harmonia axyridis* were compared on three different diets: *Cinara atlantica* (Wilson), *Brevicoryne brassicae* (L.), and frozen eggs of *Anagasta kuehniella* (Zeller) (diets 1-3). All three diets were evaluated at 25°C, 70% RH and 12L:12D photoperiod with 15 replicates. Faster development was obtained on *A. kuehniella* eggs, but differences were only significant in the first, third and fourth instars. Fecundity and fertility were higher on aphid species, the number of eggs per day and egg mass being highest on *C. atlantica*. There was no significant difference among diets with respect to pre-oviposition or oviposition periods, or total longevity. The net reproductive rate was highest on diet 2, followed by diets 1 and 3. Generation time (T) decreased from diets 3-1, but intrinsic rates of increase (r_m) were very similar for all three. The finite rate of population increase (λ) was 1.1389, 1.1503 and 1.1275 for diets 1-3, respectively. Doubling time (DT) was greatest (7.46 d) on diet 2, lower on diet 3 (5.78 d) and lowest on diet 1 (5.33 days). The results indicate that prey type affect both the life cycle and the life table of *H. axyridis*, and better results are obtained with aphids, especially *C. atlantica*, although *A. kuehniella* eggs are also a suitable food source.

Key words: *Anagasta kuehniella*, *Brevicoryne brassicae*, *Cinara atlantica*, development, fecundity

EFFECT OF A NEW NANO-FORMULATED PYRETHRIN ON *COCCINELLA SEPTEMPUNCTATA*

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Toxicity and sub-lethal effects of a new nano-formulated pyrethrin were examined on the predator *Coccinella septempunctata* with respect to the nanoscale potential to create environmentally responsible products. Pyrethrin was nano-formulated in water-in-oil (w/o) microemulsions based on safe, biocompatible materials such as lemon oil terpenes as dispersant, polysorbates as stabilizers and mixtures of water and glycerol as the dispersed aqueous phase. Laboratory bioassays were conducted in which second and third larval instars (3-5 day-old larvae) of the predator were exposed individually to dry residues of the insecticide and then fed *Aphis fabae* ad libitum until pupation. Adults emerging from pupae were used to determine female pre-oviposition period and fecundity (over 15 days). Survival analysis indicated no effect of the nano-formulated pyrethrin on the survival of *C. septempunctata* larvae, the pre-oviposition period, or female fecundity.

Key words: insecticide, fecundity, nanotechnology, survival

SUSCEPTIBILITY OF *NASONOVIA RIBISNIGRI* DEVELOPMENTAL STAGES TO *BEAUVERIA BASSIANA* AND THE EFFECT OF INFECTION ON ADULT FECUNDITY

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The susceptibility of different developmental stages (first instar, second instar, fourth instar alatae and apterae adult) of the lettuce aphid, *Nasonovia ribisnigri*, to the entomopathogenic fungus, *Beauveria bassiana*, was investigated under laboratory conditions. Each stage was exposed to three concentrations of the fungus (1×10^4 , 1×10^6 and 1×10^8 conidia ml⁻¹). Furthermore, the effect of fungal infection on the fecundity of *N. ribisnigri* adults was also investigated. Apterous adults and alate fourth instar nymphs were more susceptible to infection than first or second instars. Mortality at all stages was dosage-dependent, with the highest concentration producing the highest mortality (77, 73, 95 and 94% for first instars, second instars, alate fourth instars and apterous adults, respectively). Newly molted apterous adults exposed to high spore concentration of *B. bassiana* produced significantly fewer nymphs (2.93 ± 0.27) per surviving adult per day than controls (3.76 ± 0.12), but no significant difference was observed between control and low (3.64 ± 0.12) or medium (3.48 ± 0.18) spore concentrations. Fourth instar alate nymphs exposed to high and medium spore concentrations of *B. bassiana* produced significantly fewer nymphs (1.94 ± 0.21 and 1.98 ± 0.15 respectively) than controls (2.89 ± 0.16), but there was no significant difference between aphids inoculated with control and low (3.03 ± 0.13) spore concentrations.

Key words: Entomopathogenic fungus, mortality, dose, reproduction

DETERMINATION OF INTERCROP MOVEMENT OF CARABIDS BETWEEN ADJACENT ALFALFA AND MAIZE USING RUBIDIUM AS A MARKER

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In the irrigated lands of northeastern Iberian peninsula, the arable landscape is characterized by a mosaic of crops with alfalfa and maize prevailing in summer. Alfalfa is a known source of natural enemies colonizing annual crops but periodic cuttings affect natural enemy populations and force them to move to field margins or other habitats. Little is known about the movement of natural enemies between maize and alfalfa when the crops are adjacent or the role of maize as a refuge for natural enemies when alfalfa is cut. We measured the movement of the three most abundant ground beetles, *Calathus fuscipes*, *Poecilus cupreus* and *Pseudophonus rufipes* (Coleoptera: Carabidae) between adjacent alfalfa and maize fields before and after alfalfa cuttings. Plants within a 100 m² quadrat within each field were sprayed with rubidium chloride and beetles were subsequently collected in pitfall traps placed inside the adjacent crop and along the edges of fields. The three species moved continually between alfalfa, maize across field borders both before and after alfalfa cuttings. Our results revealed that field edges play an important role in the movement of ground beetles, although the pattern of movement was different for each species. Cutting alfalfa increased the percentage of rubidium-marked *C. fuscipes* and *P. cupreus* emigrating from alfalfa and entering maize fields, whereas *P. rufipes* showed no response. Our results showed that carabids move continuously between alfalfa and maize without being forced by any crop management practices. However, when alfalfa is cut, field borders and maize fields become refuge habitats. These results support the inference that field borders and adjacent annual crops play an important role in predator conservation in landscapes with managed perennial crops.

Key words: biological control, epigeal predators, landscape management, rubidium, spillover

PARASITISATION OF COCCINELLID SPECIES IN OXFORDSHIRE AND LONDON AND FIRST RECORD OF AN *HARMONIA* *AXYRIDIS* – PHORID ASSOCIATION FROM ITALY

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The enemy release hypothesis (ERH) states that the invasion success of an exotic species is partly related to the scarcity of its antagonists (i.e. parasitoids) in the introduced range compared to the original distribution. The exotic *Harmonia axyridis* arrived in the UK in 2004 and has rapidly spread in the territory becoming at present one of the most abundant ladybird species in several habitats. We investigated at six years from *H. axyridis* arrival what impact the parasitoids *Phalacrotophora* spp. (Diptera: Phoridae) have on the populations of the exotic ladybird and of the natives *Adalia bipunctata*, *A. decempunctata* (considered here as one group: *Adalia* spp.) and *Coccinella septempunctata* L. in different Oxfordshire and London habitats. Pupae of the target ladybirds were collected from the field and reared under controlled environmental conditions. Total parasitisation rate (Phoridae + Tetrastichinae) was higher in *Adalia* spp. (5.87%) and *C. septempunctata* (4.38 %) than in *H. axyridis* (0.77%). Phorid parasitisation was significantly higher in *Adalia* spp. (5.07%) than in *C. septempunctata* (0.80%) and *H. axyridis* (0.56%). Emerged phorids belong to *Phalacrotophora fasciata* and *P. berolinensis*. Results of this one year survey suggest that ERH could be relevant to *H. axyridis* and can support its success in dominating coccinellid guilds in the invaded UK habitats. Moreover in 2011 a survey of coccinellid pupae was carried out in northern Italy. *P. fasciata* emerged from a *H. axyridis* pupa, representing first host-parasitoid association record from Italy.

Key words: biological invasion, enemy release hypothesis, invasive species

APHIDOPHAGOUS MITES IN WESTERN AND EASTERN PARTS OF IRAN

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Most of Acari species are beneficial to agricultural systems. Some of them have two roles in biological control; in larval stages they are parasitic and predatory in their post larval stages on the variety insect and mites. In this study we have collected and identified parasitic mites with associated aphid in some parts of Iran. Mites were mounted on slides in modified Hoyer's medium and studied by means of an Olympus BX51 phase contrast microscope. In this study 7 species were collected and identified. Parasitic mites according their host are as follows: *Erythraeus* (Z.) *kurdistanensis* Khanjani and Ueckermann, 2005 from unknown aphids; *Erythraeus* (E.) *mirabii* Khanjani et al. 2007, from walnut aphid *Chromaphis juglandicola* (Kaltenbach); *E. (E.) iranicus* Saboori and Akrami, 2001 from pistachio and *Aphis gossypii* Glover; *Allothrombium ovatum* Zhang & Xin, from pomegranate aphid, *Aphis punicae* Passerini; *Praphanolophus saboori* Khanjani et al. 2009, from *Aphis punicae* Passerini; *Allothrombium pulvinum* Ewing from types of different aphid, *A. tritici* from Russian wheat aphid, *Duraphis noxia* (Mordvilko); *Abrolophus nouriganbalani* Khanjani et al. 2009 from unknown aphid. Most of these parasitic mite were collected from west of Iran. Amongst them *A. pulvinum* is widely distributed in Iran.

Key words: Acari, biological control, parasite, predator

WHAT INFLUENCES THE PHYTOPHAGY OF THE *OMNIVOROUS MULLEIN* BUG, *CAMPYLOMMA VERBASCI* (HEMIPTERA : MIRIDAE)?

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The mullein bug, *Campylomma verbasci* Meyer (Hemiptera: Miridae) is an important pest in North American apple orchards in specific areas/periods. The zoophytophagous insect may be considered noxious when the larval instars puncture the growing apple fruits during and just after apple bloom. After that, the mirid becomes beneficial by preying on aphids (Hemiptera: Aphididae) and mites (Acarina: Tetranychidae). The objective of the present study was 1) to study the influence of the apple cultivar on the phytophagy of the mullein bug in the laboratory and on damage caused to apple fruit in the field, 2) to evaluate the effect of the size of apple fruit on the phytophagy of the bugs and 3) to investigate the influence of prey density (aphids and mites) on the phytophagy of the mullein bug in the laboratory and the influence of bug density and presence of preys on damage caused to apple fruit in the field. In the laboratory, fourth instar larvae were observed individually in Petri dishes containing agar and an apple fruit during 15 min. Three apple cultivars were tested and three fruit sizes for the cultivar most sensitive to phytophagy. Two types of prey were tested: *Aphis pomi* DeGeer (Hemiptera: Aphididae) and *Panonychus ulmi* Koch (Acarina: Tetranychidae), at four densities (0, 4, 8 and 16). In the field, young nymphs were caged in single branch sleeve cages at bloom. Seven apple cultivars were tested. Three prey densities (0, 10 or 40 red mites) and three mullein bug densities (0, 3 or 9) were tested. The number of feeding punctures was greater on Red Delicious and for fruit smaller than 10 mm. The number of feeding punctures was lower in the presence of prey, but the number of punctures was not influenced by prey density. In the field, Red Delicious cultivar was the most sensitive to damage, and the magnitude of damage was greater in the absence of prey. There was also more damage when density of mullein bugs was higher.

Key words: *Campylomma verbasci*, Heteroptera, Miridae, zoophytophagy, apple orchards

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