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Entomophagous insects – an introduction

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Abstract

This special issue contains papers presented at the 6th International Entomophagous Insects Conference. Entomophagous insects consume other insects. They are a fundamental component of ecosystems and are extensively used as biocontrol agents. The first article reviews the role of ladybirds in biological control and the second reviews the biological control of stink bugs. The following nine research articles cover the rearing, behavior, life history, and ecology of parasitoid and predator species.

Entomophagous insects are insects that consume other insects. There are two main types: predators that prey on insects, and parasitoids that lay their eggs and develop in or on other insects. Predatory species are common among most insect orders, including dragonflies (Odonata), mantids (Mantodea), true bugs (Heteroptera, Hemiptera), thrips (Thysanoptera), lacewings (Neuroptera), beetles (Coleoptera), and some groups of flies (Diptera), such as hoverflies (Syrphidae) and robber flies (Asilidae). The parasitoid life style is taxonomically more restricted to wasps (mostly Parasitica, Hymenoptera) and flies (Tachinidae, Diptera).

Insect predators and parasitoids are fundamental components of trophic networks and important for ecosystem functioning. They also provide major ecosystem services as pest control agents (Colazza et al., 2017; Heimpel & Mills, 2017; Le Hesran et al., 2019). Classical, conservation, and augmentative biological control are largely based on the exploitation of these amazingly diverse entomophagous insects. Focus has traditionally been on parasitoid wasps, but predatory insects, such as lady beetles (Coccinellidae) and predacious bugs (Miridae, Heteroptera) are also frequently used as biocontrol agents, as well as predatory mites (Acari) that do not belong to the Insect class. Study of the biology of entomophagous insects is therefore important from both a fundamental and applied perspective, in line with the scope of Entomologia Experimentalis et Applicata.

The issue starts with two review articles on biological control. Rondoni et al. (2021) review the use of ladybirds (Coleoptera: Coccinellidae) in classical biological control and the associated benefits and environmental risks. The paper also provides several case studies, centered on introduced species such as *Coccinella septempunctata* L., *Harmonia axyridis* (Pallas), and *Hippodamia variegata* (Goeze), and analyzes the data obtained from the BIOCAT database of classical biocontrol programs. At least 212 ladybird species have been released worldwide during about 130 years, with variable but encouraging results.

Conti et al. (2021) then review the global state and future prospects of stink bug biological control, focusing on *Halyomorpha halys* (Stål), *Bagrada hilaris* (Burmeister), *Piezodorus guildinii* (Westwood), *Nezara viridula* (L.), and *Murgantia histrionica* (Hahn) (Hemiptera: Pentatomidae). The review describes several case studies of classical and conservation biological control and suggests strategies to improve the efficacy of biocontrol agents through habitat manipulation and exploitation of their chemical ecology. Additionally, it provides prospects for sustainable control methods, such as behavioral manipulation of adult stink bugs and plant resistance.

The biological control of invasive stink bugs (Hemiptera: Pentatomidae) is also investigated by Moraglio et al.

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(2021) who report on the field collection of egg parasitoids on native Pentatomidae and Scutelleridae in Northwestern Italy and their evaluation against the invasive *H. halys* under laboratory conditions. With a few negligible exceptions, *Trissolcus kozlovi* Rjachovskij is the only species that was able to complete development in *H. halys* eggs (about 20%), whereas all other tested *Trissolcus* species were found to induce host egg abortion, which may also negatively affect pest populations.

Two more papers in the special issue are dedicated to the use of parasitoids and predators in biological control. Abdi et al. (2021) focus on mass rearing and parasitoid quality. They evaluated an alternative host, *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae), for rearing *Sclerodermus brevicornis* (Kieffer) (Hymenoptera: Bethylidae), a candidate agent for biological control of longhorn beetles (Coleoptera: Cerambycidae) in Europe. By examining several aspects of parasitoid oviposition behavior and reproductive success, this study shows that *C. cephalonica* is suitable as an alternative host for mass rearing of *S. brevicornis*.

Dindo et al. (2021) then investigated the efficacy of *Monarda fistulosa* L. (Lamiaceae) hydrolate as antimicrobial agent in artificial media for *in vitro* rearing of the parasitoid *Exorista larvarum* (L.) (Diptera: Tachinidae), as an alternative to the use of antibiotics (gentamicin). Although effective in controlling bacterial load, the *M. fistulosa* hydrolate supplemented to the artificial media significantly reduced *E. larvarum* development from the egg to the adult stage compared to gentamicin-supplemented medium, but not the number of eggs laid by the emerging females. The authors conclude that *M. fistulosa* hydrolate may be considered as a promising candidate to replace gentamicin as rearing substrate.

Aspects of predator behavior are addressed by Duarte et al. (2021) who report on intraguild predation (IGP) and cannibalism within Dicyphini (Hemiptera: Miridae). Predaceous mirids are common in horticultural crops and some species are also released for biological control, which might displace naturally occurring species. The authors evaluated whether the decrease in abundance of the native *Dicyphus cerastii* Wagner might depend on intraguild competition with *Nesidiocoris tenuis* (Reuter) or with the naturally occurring *Macrolophus pygmaeus* (Rambur). Results of laboratory experiments, carried out with first instars, show that heterospecific and conspecific competition occurred only in the absence of alternative food, and that IGP was asymmetrical only between *D. cerastii* and *N. tenuis*. However, this favored *D. cerastii*. Therefore, under laboratory conditions, IGP did not explain the abundance shift between the two species, which needs further investigations.

In the work presented by Withers et al. (2021), parasitoid behavior is used as a tool to evaluate the ecological host range of *Eadya daenerys* Ridenbaugh (Hymenoptera: Braconidae), a candidate biological control agent of the invasive eucalyptus pest *Paropsis charybdis* Stål (Coleoptera: Chrysomelidae, Chrysomelinae) in New Zealand. Herbivore larvae were tested on eucalyptus plants, hence with cues from both hosts and their host plant, and the parasitoid response was evaluated towards larvae of nine closely related species – including a native species, invasive species, and introduced weed biocontrol agents. Parasitoids showed significantly lower on-plant attack rates against non-target species compared to the target larvae. Overall, the results show that the candidate biocontrol agent *E. daenerys* prefers the target pest *P. charybdis* but might also attack other eucalyptus-feeding invasive paropsines (Chrysomelinae).

The chemical ecology of entomophagous insects is addressed focusing both on the functional morphology of antennal sensilla and on the exploitation of semiochemicals to improve predator efficacy. Sevarika et al. (2021) investigated the antennal sensilla of *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) using scanning and transmission electron microscopy. Various types of sensilla (chemoreceptors, mechanoreceptors, and thermo-hygroreceptors) and their distributions are described. Peculiar characters previously unknown for ladybirds include the high concentration of sensory structures at the distal part of the apical antennomere and the discovery of antennal glands associated with it. No sexual dimorphism was found. These antennal sensilla and glands might have relevance especially in the interspecific communication of this invasive predator.

Silva et al. (2021) then investigated the response of the predaceous mirids *N. tenuis*, *M. pygmaeus*, and *Dicyphus bolivari* (Lindberg) (Hemiptera: Miridae) to synthetic host-induced plant volatiles in a Y-tube olfactometer. These predators responded to several compounds, depending on species, and all were attracted to (*Z*)-3-hexenyl propanoate, (*Z*)-3-hexenyl acetate, and methyl salicylate, suggesting potential for their use under field conditions to improve predation efficacy.

Another study focuses on parasitoid landscape ecology, showing the effects of various host plants and two hosts on the performance of the generalist gregarious larval ectoparasitoid *Euplectrus platyhypenae* Howard (Hymenoptera: Eulophidae) (Traine et al., 2021). Under laboratory conditions, the best combination of host and host plant for the parasitoid's performance was *Spodoptera frugiperda* Smith (Lepidoptera: Noctuidae) on maize. On this crop, the parasitoid performed better on *S. frugiperda* than on *Spodoptera latifascia* Walker, whereas when caterpillars were reared on squash, the parasitoid performed better on

S. latifascia instead. Additionally, parasitoid performance was increased on cultivated compared to wild Lima bean leaves. Thus, it can be expected that, in a mixed-crop system, this generalist parasitoid can switch among hosts and host plant species, with possible improvement of the overall pest control efficacy.

Physiology and life-history strategies are crucial aspects of the biology of parasitoids. Evans (2021) studied the factors influencing the expression of partial bivoltinism in *Tetrastichus julis* Walker (Hymenoptera: Eulophidae). The parasitoid was introduced to North America against its univoltine host *Oulema melanopus* (L.) (Coleoptera: Chrysomelidae). The percentage of *T. julis* that forgo diapause and emerge from host cocoons was found to decline with the summer advancing. Additionally, at a given time of the season, it increased as the number of conspecifics with which an individual shared a host increased. Therefore, a trade-off appears to exist for the parasitoids in diapausing, which offers greater success in finding and ovipositing in host larvae the following spring, but also increases the chance of dying during overwintering.

The articles in this special issue are a small but representative selection of the papers presented at the 6th International Entomophagous Insects Conference (IEIC6). They provide novel biological knowledge of both predator and parasitoid species from the most frequently used insect orders in biological control (parasitoid wasps, ladybirds, predaceous bugs). They demonstrate that basic and applied research on entomophagous insects is an active field, which may gain increased interest due to the growing need of improving sustainable pest control methods to reduce the release of synthetic pesticides in the environment as well as global crop loss.

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