frontiers in Ecology and Evolution

EDITORIAL
published: 07 November 2019
doi: 10.3389/fevo.2019.00425

Editorial: Ecosystem Services and Disservices Provided by Plant-Feeding Predatory Arthropods

Maria L. Pappas[1]*, *George D. Broufas*[1]*, *Alberto Pozzebon*[2]*, *Carlo Duso*[2]* and *Felix Wäckers*[3,4]*

[1] Department of Agricultural Development, School of Agricultural and Forestry Sciences, Democritus University of Thrace, Orestiada, Greece, [2] Department of Agronomy, Food, Natural Resources, Animals, Environment, University of Padua, Padua, Italy, [3] Biobest, Westerlo, Belgium, [4] Lancaster Environment Centre, Lancaster University, Lancaster, United Kingdom

Keywords: omnivory, zoophytophagous predator, plant-feeding, ecosystem services, biological control

OPEN ACCESS

Edited by:
Klaus Birkhofer,
Brandenburg University of Technology Cottbus-Senftenberg, Germany

Reviewed by:
Vesna Gagic,
University of Belgrade, Serbia
Adrien Rusch,
Institut National de la Recherche Agronomique (INRA), France

***Correspondence:**
Maria L. Pappas
mpappa@agro.duth.gr
George D. Broufas
gbroufas@agro.duth.gr
Alberto Pozzebon
alberto.pozzebon@unipd.it
Carlo Duso
carlo.duso@unipd.it
Felix Wäckers
felix.wackers@biobest.be

Specialty section:
This article was submitted to Agroecology, a section of the journal Frontiers in Ecology and Evolution

Received: 22 August 2019
Accepted: 21 October 2019
Published: 07 November 2019

Citation:
Pappas ML, Broufas GD, Pozzebon A, Duso C and Wäckers F (2019) Editorial: Ecosystem Services and Disservices Provided by Plant-Feeding Predatory Arthropods. Front. Ecol. Evol. 7:425. doi: 10.3389/fevo.2019.00425

Editorial on the Research Topic

Ecosystem Services and Disservices Provided by Plant-Feeding Predatory Arthropods

INTRODUCTION

Omnivorous arthropods are important components of natural and agricultural settings, capable of exploiting both animal and plant food (Coll and Guershon, 2002). Certain omnivorous pests, such as herbivorous thrips, are also capable of consuming prey (Trichilo and Leigh, 1986; Agrawal et al., 1999; van Maanen et al., 2012), whereas diet mixing by zoophytophagous predators such as mirids and generalist phytoseiid mites enables their persistence in the field when prey is scarce (Coll and Guershon, 2002). Plant food exploitation may thus enhance ecosystem services such as biological control these predators provide.

In addition, among omnivorous arthropods, certain zoophytophagous predators (i.e., predators that feed on both prey and plant) have been shown to engage in plant-mediated interactions between microbes and herbivores (e.g., Battaglia et al., 2013; Prieto et al., 2017; Pappas et al., 2018) and to be strongly affected by plant-related factors such as nutritional quality and/or plant defense traits. Despite the importance and wide distribution of omnivorous predators in diverse ecosystems, research so far has mainly focused on their predation potential against key pests of crops.

This Research Topic includes studies that aim to understand and potentially improve ecosystem services provided by omnivorous arthropods. Unexplored ecosystem services as well as disservices are also addressed. Here, we highlight some of the major points arising from these studies.

ALTERNATIVE FOODS TO SUPPORT PLANT-FEEDING PREDATORS

Predatory mites of the family Phytoseiidae play key role in controlling a number of mites and insects that damage crops all over the world. McMurtry (1992) emphasized the role of generalist predatory mites and stressed their capacity to persist on plants when prey is virtually absent by exploiting alternative foods (McMurtry and Croft, 1997; McMurtry et al., 2013). An interesting contribution to this field came from the paper by Sugioka et al.. Since many generalist predatory mites feed on pollen, authors hypothesized that antioxidants in pollen could protect their germ cells from UVB radiation and radiant heat. They compared the effects of pollen or spider mites on the generalist predatory mite *Neoseiulus californicus*. Results showed that protective antioxidant components in pollen improved UVB resistance in *N. californicus*, contributing to their adaptation to solar radiation. In addition, Samaras et al. hypothesized that pollen provisioning results in efficient exploitation of marginally suitable prey species by generalist phytoseiid predators. Cattail pollen was provided as supplementary food source for the phytoseiid mite *Amblydromalus limonicus*, a biological control agent of thrips and whiteflies in greenhouse crops (Knapp et al., 2013), when feeding on a low-quality prey, the two spotted spider mite, *Tetranychus urticae*. Pollen provisioning was shown to result in reduced dispersal of *A. limonicus*, and to favor their predatory performance on spider mites suggesting that plant-based food sources may expand the range of prey species plant-feeding predators can exploit, while also increasing their efficiency in biological control.

Among predatory insects, coccinellids, have also been observed to consume non-prey foods such as nectar and pollen (Hodek et al., 2012). In their study, He and Sigsgaard assessed the effects of aphids species and Mediterranean flour moth eggs, as well as flowers, pollen, and sugar solutions on *Adalia bipunctata* performance. Results suggest that flowering plants can prolong larval survival and adult longevity when prey is absent and that sugar feeding results in adults of high lipid content. These findings highlight the role of non-prey foods in sustaining predator populations and could be useful in managing functional biodiversity in agricultural settings.

ECOSYSTEM DISSERVICES

Potential backslash of promoting zoophytophagous predators is the risk associated with damage inflicted by their phytophagy on crops (Castañé et al., 2011; Dumont et al.). In their systematic review article, Puentes et al. provide a synthesis of publications trends to determine the frequency of plant damage by omnivores and how often their impact on plants is considered or quantified in current literature. Results show that costs to plants are addressed only seldomly and current knowledge on omnivore feeding effects on plants is mainly based on studies on tomato and associated zoophytophagous biocontrol agents. In view of the presented bias, authors stress the need for negative effects on plants to be addressed in studies dealing with effects of zoophytophagous predators. They also highlight the need of studying other plant-predator systems, besides tomato, to generalize conclusions about plant costs of predator phytophagy.

Among zoophytophagous mirids, there are well-known examples where their use in biological control constitutes potential risks (Castañé et al., 2011; Puentes et al.). The work by Sanchez et al., is an attempt to shed light on the impact of *Macrolophus pygmaeus* in the real context of use. Using a complete factorial randomized design, the authors investigated the effect of *M. pygmaeus* on the reduction in the populations of tomato pests and its impact on tomato productivity in different greenhouses in the south of Spain. The results indicated that early establishment of high populations of the mirid, can provide better pest control but can also induce yield losses, and the balance between pros and cons cannot always be in favor of the use of the mirid. According to the authors, a better understanding of the factors that increase the risks associated with *M. pygmaeus* is necessary to ensure the economic viability of its use. In their review article, Dumont et al. proposed the adoption of an evolutionary approach in the optimisation of biological control services provided by plant-feeding predators. In the first part of their review article, trait-specific genetic improvement is proposed as a process to increase "services" (i.e., beneficial zoophagy), and decrease "disservices" (i.e., detrimental phytophagy) provided by zoophytophagous predators. In the second part, potential implications of the selection process on ecological interactions with the host plant, prey and competitors, and potential benefits and challenges of the evolutionary approach in the context of different biological control strategies are discussed.

Finally, Thurman et al. address the range of beneficial and harmful effects that can be generated by generalist predators, focusing on weaver ants. Weaver ants are an excellent model, as they represent the oldest example of an organism being successfully used in biological control, yet they also clearly have negative impacts by guarding honeydew producing pests, attacking other predators and pollinators and using plant shoots to build their tree nests (Way and Khoo, 1992). In this paper, the authors review the literature to assess the net outcome of these variable interactions to agricultural production. They show that the overall effect is almost exclusively positive with broad reaching benefits to crop productivity.

INTERACTIONS IN COMPLEX FOOD WEBS

Knowledge on plant-predator interactions is essential to exploit ecosystem services provided by zoophytophagous predators. Maselou et al. studied the behavioral responses of *M. pygmaeus* to volatiles emitted by host plants, in the presence/absence of prey, or floral resources. They also analyzed plant volatile blends and showed significant differences in volatiles emitted by infested and uninfested plants. These results could be useful to understand ecological interactions among mirid predators and their host plants, and to design strategies to enhance biological control. In addition, Tixier analyzed plant traits and the potential relationships between plants and phytoseiids to identify favorable plants to key predatory mite species. This approach was useful to calculate the probability to detect certain predatory mite species on crops and non-crop plants. The author suggests the involvement of plant experts in future attempts to associate plant traits (or plant phylogeny) and Phytoseiidae diversity using meta-analyses.

Indirect interactions in complex food webs between herbivores, omnivorous pests and natural enemies are the focus of the paper by Vaello et al.. It is shown that the presence of pest thrips that feed on both plants and arthropods reduces the performance of plants and aphids. Interestingly, syrphids, whose larvae are important aphid predators, but may also feed on thrips, were shown to be unaffected by thrips in terms of larval development, yet suffered reduced fecundity as adults. Moreover, adult hoverflies avoided thrips infested plants or thrips aggregation pheromones. These examples show the complex and sometimes idiosyncratic interactions in multitrophic food webs.

Underlining this, Eschweiler et al. studied the interaction in tomato between an endophytic, non-pathogenic strain of

Fusarium oxysporum (Fo162) restricted to roots, the greenhouse whitefly *Trialeurodes vaporariorum* and the zoophytophagous predator *M. pygmaeus*. Adding to recent studies highlighting the ability of beneficial soil microbes to impact the performance and behavior of aboveground zoophytophagous mirid predators via the plant (Battaglia et al., 2013; Prieto et al., 2017; Garantonakis et al., 2018; Pappas et al., 2018), they show that tomato inoculation with Fo162 results in enhanced whitefly control, increased yield and reduced number of fruits with blossom-end rot potentially providing a new preventive biological control strategy against the greenhouse whitefly.

CONCLUSIONS

In summary, this special issue provides an overview of studies dealing with omnivorous arthropods and provided ecosystem services/disservices. An attempt has been made in this special issue to identify gaps and challenges, as well as to highlight future research directions with the aim to reduce provided disservices and identify novel tools in the use of plant-feeding predators in biological pest control.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

FUNDING

MP was supported by the Onassis Foundation (grant R-ZJ 003). AP was supported by DAFNAE-University of Padova through BIRD167802/16.

REFERENCES

Agrawal, A. A., Kobayashi, C., and Thaler, J. S. (1999). Influence of prey availability and induced host-plant resistance on omnivory by western flower thrips. *Ecology* 80, 518–523. doi: 10.1890/0012-9658(1999)080[0518:IOPAAI]2.0.CO;2

Battaglia, D., Bossi, S., Cascone, P., Digilio, M. C., Prieto, J. D., Fanti, P., et al. (2013). Tomato below ground-above ground interactions: *Trichoderma longibrachiatum* affects the performance of *Macrosiphum euphorbiae* and its natural antagonists. *Mol. Plant Microbe Interact.* 26, 1249–1256. doi: 10.1094/MPMI-02-13-0059-R

Castañé, C., Arnó, J., Gabarra, R., and Alomar, O. (2011). Plant damage to vegetable crops by zoophytophagous mirid predators. *Biol. Control* 59, 22–29. doi: 10.1016/j.biocontrol.2011.03.007

Coll, M., and Guershon, M. (2002). Omnivory in terrestrial arthropods: mixing plant and prey diets. *Annu. Rev. Entomol.* 47, 267–297. doi: 10.1146/annurev.ento.47.091201.145209

Garantonakis, N., Pappas, M. L., Varikou, K., Skiada, V., Broufas, G. D., Kavroulakis, N., et al. (2018). Tomato inoculation with the endophytic strain *Fusarium solani* K results in reduced feeding damage by the zoophytophagous predator *Nesidiocoris tenuis*. *Front. Ecol. Evol.* 6:126. doi: 10.3389/fevo.2018.00126

Hodek, I., van Emden, H. F., and Honěk, A. (2012). *Ecology and Behaviour of the Ladybird Beetles (Coccinellidae).* Chichester: Blackwell Publishing Ltd.

Knapp, M., Van Houten, Y., Hoogerbrugge, H., and Bolckmans, K. (2013). *Amblydromalus limonicus* (Acari: Phytoseiidae) as a biocontrol agent: literature review and new findings. *Acarologia* 53, 191–202. doi: 10.1051/acarologia/20132088

McMurtry, J. A. (1992). Dynamics and potential impact of 'generalist' phytoseiids in agroecosystems and possibilities for establishment of exotic species. *Exp. Appl. Acarol.* 14, 371–382. doi: 10.1007/BF01200574

McMurtry, J. A., and Croft, B. A. (1997). Life-styles of Phytoseiid mites and their roles in biological control. *Annu. Rev. Entomol.* 42, 291–321. doi: 10.1146/annurev.ento.42.1.291

McMurtry, J. A., De Moraes, G. J., and Sourassou, N. F. (2013). Revision of the lifestyles of phytoseiid mites (Acari: Phytoseiidae) and implications for biological control strategies. *Syst. Appl. Acarol.* 18, 297–320. doi: 10.11158/saa.18.4.1

Pappas, M. L., Liapoura, M., Papantoniou, D., Avramidou, M., Kavroulakis, N., Weinhold, A., et al. (2018). The beneficial endophytic fungus *Fusarium solani* strain K alters tomato responses against spider mites to the benefit of the plant. *Front. Plant Sci.* 9:1603. doi: 10.3389/fpls.2018.01603

Prieto, J. D., Castañé, C., Calvet, C., Camprubi, A., Battaglia, D., Trotta, V., et al. (2017). Tomato belowground–aboveground interactions: *Rhizophagus irregularis* affects foraging behavior and life history traits of the predator *Macrolophus pygmaeus* (Hemiptera: Miridae). *Arthropod Plant Interact.* 11, 15–22. doi: 10.1007/s11829-016-9465-5

Trichilo, P. J., and Leigh, T. F. (1986). Predation on spider mite eggs by the western flower thrips, *Frankliniella occidentalis* (Thysanoptera: Thripidae), an opportunist in a cotton agroecosystem. *Environ. Entomol.* 15, 821–825.

van Maanen, R., Broufas, G., Oveja, M. F., Sabelis, M. W., and Janssen, A. (2012). Intraguild predation among plant pests: western flower thrips larvae feed on whitefly crawlers. *Biocontrol* 57, 533–539. doi: 10.1007/s10526-011-9433-z

Way, M. J., and Khoo, K. C. (1992). Role of ants in pest management. *Annu. Rev. Entomol.* 37, 479–503.

Conflict of Interest: FW was employed by company Biobest.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.