Carabid beetle community responses to integrated management practices in commercial crops in Fife, Scotland

Vol. 156
2022

IOBC-WPRS

Working Group „Landscape Management for Functional Biodiversity"

Proceedings of the 9th Meeting at Milan (Italy)

7-10 June, 2022

Edited by: Bärbel Gerowitt, John Holland, Felix Bianchi, Graham Begg, Camilla Moonen, Simone Marini, Augusto Loni, Gail Jackson, Louis Sutter, Daniela Lupi

IOBC-WPRS

The IOBC-WPRS Bulletin is published by the International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palearctic Regional Section (IOBC-WPRS).

Le Bulletin OILB-SROP est publié par l'Organisation Internationale de Lutte Biologique et Intégrée contre les Animaux et les Plantes Nuisibles, section Regionale Ouest Paléarctique (OILB-SROP).

The Publication Commission of the IOBC-WPRS:

Dr. Ute Koch
Schillerstrasse 13
D-69509 Moerlenbach, Germany
Tel +49-6209-1079
e-mail: u.koch_moerlenbach@t-online.de

Dr. Annette Herz
Julius Kühn-Institute (JKI)
Federal Research Center for Cultivated Plants
Plant Protection in Fruit Crops and Viticulture
Schwabenheimer Str. 101
D-69221 Dossenheim, Germany
Tel +49 3946 474965
e-mail: Annette.Herz@julius-kuehn.de

Address General Secretariat:

Paula Baptista
Polytechnic Institute of Bragança
School of Agriculture
Campus de Santa Apolónia
5300-253 Bragança, Portugal
Phone: +351 273 303 332
e-mail: pbaptista@ipb.pt

ISBN 978-92-9067-342-2

Web: http://www.iobc-wprs.org

Darmstadt, 2022

Contents

Organization

Local organizers:
Daniela Lupi
Sara Savoldelli
Costanza Jucker

Convenor:
Bärbel Gerowitt,

Co-Convenor:
Graham Begg

Scientific Committee:
Bärbel Gerowitt,
Daniela Lupi
Graham Begg,
John Holland,
Felix Bianchi,
Camilla Moonen,
Simone Marini,
Augusto Loni,
Gail Jackson,
Louis Sutter

Sponsors

Benvenuti/e!

… to the 9th meeting of the Working Group Landscape Management for Functional Biodiversity, organised by Daniela Lupi and her team at the University of Milano.

This workshop had a long and complicated preparation time – for sure, nobody envies Daniela and her team for applying to host the next workshop three years ago in the Netherlands. Cancellation, forwarding and the long-lasting unsecurity characterize the process – the real reason was affecting all of us. I am happy that Daniela was brave enough to carry on so that we now can meet physically in Milano, and facilitate also on-line participation for those who cannot travel.

Mille grazie!

Landscape management for functional biodiversity is "up to date". No doubt, the terrible war of Russia against the Ukrainian people moved the coordinates how farmers, the public and politicians think about biodiversity in farmed landscapes. However, researchers also doubt that dropping back to "farm intensively wherever possible" is a clever and sustainable idea. Finding a good balance and make use of the support of biodiversity to safe and secure produce food is what we all urgently need. I am convinced that this meeting adds to this big issue with many little pieces.

This is my second and last workshop as convenor of the WG – it was a pleasure to experience the support by the local organizers and helping editors for the bulletin (Bärbel Gerowitt, John Holland, Felix Bianchi, Graham Begg, Camilla Moonen, Simone Marini, Augusto Loni, Gail Jackson, Louis Sutter, Daniela Lupi), including my co-convenor Graham Begg.

The workshop preparations were supported by Costanza Jucker and Sara Savoldelli. The IOBC publication commission finally produced the bulletin as usual in a professional way.

Thanks to all helping brains and hands.

Divertitevi!

Bärbel Gerowitt (WG-convenor)

Table of contents

Session Pest management

Session Biodiversity

Session Projects

Session Habitat management

Session Short presentations

Session Pest management

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 1-5

Pest control of *Thrips tabaci* (Thysanoptera) in onions by hoverfly larvae (Diptera: Syrphidae)

Bas Allema[1], Hilfred Huiting[1]
[1]*Wageningen University and Research, Wageningen Plant Research, Field Crops, P.O.B. 430, 8200 AK Lelystad*

Abstract: To identify factors that make natural pest control of thrips in onion successful or fail we weekly monitored thrips and their natural enemies in onion fields in the Netherlands in 2020 and 2021.

Only syrphid larvae (Diptera, Syrphidae) were found on onion plants in sufficient numbers to be a potential candidate to contribute to pest control. A diverse flower strip that is attractive to hoverflies but not to *T. tabaci* close to the onions at the time when thrips population start to increase is probably an important element for this control strategy to work.

Key words: *Thrips tabaci*, Syrphidae, population dynamics, flower margins, biocontrol, onion

Introduction

In the Netherlands *Thrips tabaci* (Lindeman) has become a problem in onions since the last decade. The current practice to control thrips is to apply insecticides whenever thrips are observed, particularly in earlier crop development stages. An alternative strategy, using flower margins to stimulate natural enemies, evokes resistance among farmers because these margins are perceived as a source of thrips rather than a contribute to pest control.

We selected a group of farmers that is already working with methods to reduce insecticides and studied on their onion fields the population dynamics of thrips and its natural enemies. In the first year we were interested in a potential effect of a flower margin on thrips control at different distances from the margin and used the same flower margin on all farms. In the second year we were interested in the effect of different types of flower margins on thrips control and monitored only at close distance from the margin.

Materials and methods

Monitoring took place in six onion fields in 2020 and nine onion fields in 2021 divided over three regions in the province North Holland in the Netherlands. All fields were either bordered by a flower margin or the flower strip was sown in the spray tracks. In 2020 all farmers installed a field margin with a mixture of buckwheat (*Fagopyrum esculentum* Moench) and three umbellifer species (*Coriandrum sativum* L., *Foeniculum vulgare* Mill, *Ammi majus* L.) and monitoring took place at 15, 30, 60 and 90 m distance from the flower margin depending on the width of the fields, which ranged from 50-250 m. In 2021 farmers were free to choose the composition of flowers and the species composition was in general more diverse. Monitoring took place at 1.5 and 15 m from the flower margin.

In both years, onions were sown between late March and late April and the flowers were sown at the same time or as soon as possible after the onions were sown. Onion variety, soil management or fertilizer application all differed between farmers.

Thrips adults and nymphs and their natural enemies were counted in a 7-11 day interval on onion plants by examining all the leaves from 29 May till 17 August in 2020 and from 17 June till 26 August in 2021. In both years, at each distance from the flower margin 15 to 20 plants were examined with a distance of about 10 m between two plants. In 2021 the cumulative amount of precipitation was measured weekly per field with a rain gauge.

At the field in Anna Paulowna in 2021, three different flower strips were sown in the spray tracks and on 12 August these strips were scouted to get an impression of the number of pests and beneficial insects in the strip. These strips consisted of either only lacy phacelia (*Phacelia tanacetifolia* Bentham), only buckwheat (*F. esculentum* Moench) or a combination of lacy phacelia, buckwheat, cornflower (*Centaurea cyanus* L.) and spring cereals. At three different places at approximately 25 m distance, insects in the strip were monitored by cutting the vegetation in a square of 0.25 m^2 and tap the plants off into a tray.

Results and discussion

Presence of aboveground predators

Hoverfly larvae were by far the most abundant natural enemies of thrips that we counted on onion plants. Although we observed Neuroptera eggs (33 in 2020 and 90 in 2021), we only found 11 Neuroptera larvae in 2021. At least for our study area, which comprised the province North Holland, hoverfly larvae seem the dominant aboveground thrips predator on onions. This is in accordance with earlier work that took place in the Hoeksche Waard (South Holland), where hoverfly larvae were also the predominant predator on onion plants (van Alebeek et al., 2009). Hoverfly larvae of many species are known for their predation on aphids, but they can also feed on other soft-bodied prey such as thrips, psyllids, whiteflies, mealybugs and springtails (Rojo et al., 2003).

Population dynamics of thrips and hoverfly larvae

In 2020 we saw in total more thrips and less hoverfly larvae compared to 2021. In mid-August 2020 the overall ratio of hoverfly and thrips nymphs was 1:307. In 2021 this ratio was 1:18. Because of the low abundance of hoverfly larvae in 2020 we only present population dynamics of thrips nymphs and hoverfly larvae for 2021 (Figure 1).

For three localities (Boesingheliede, Hoofddorp and Nieuw-Vennep) the number of thrips nymphs started to increase early July, while in other localities the increase started two or more weeks later (Figure 1). The number of hoverfly larvae, however, started to increase on all fields around the same time by the start of August. The delay between predator and prey population dynamics was thus larger for the three localities mentioned above and may have contributed to a stronger increase of thrips on these fields. These three localities were all located in the southern part of the study area and it was also on these fields that the farmers decided to spray with an insecticide. In 2021 the thrips infestation declined or stabilized on all fields in August, but this cannot be solely attributed to the predation by hoverfly larvae, because in August there were also more rain showers than in July (Figure 1) and rain is also an important factor that can reduce thrips infestation (Ibrahim and Adesiyun, 2010).

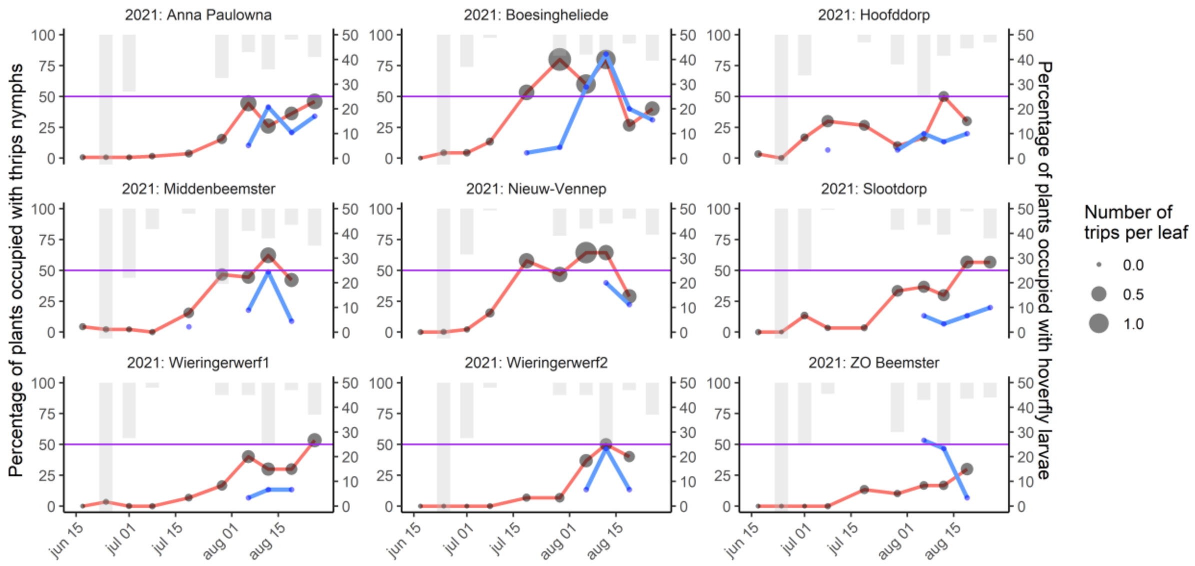


Figure 1. Colonization of onion field with thrips nymphs (red line) and hoverfly larvae (blue line). Colonization is expressed as percentage of plants that have thrips (left axis) or hoverfly larvae (right axis). The size of markers for thrips indicates the average number of thrips (adult + nymph) found per leaf. Hoverfly larvae were seldom found in more than two per plant. The purple horizontal line at 50/25 % plants occupied is to assist for comparison between fields. Gray shaded vertical bars show the relative precipitation that was recorded with a rain gauge in the preceding week. Arrows denote moments that insecticides were applied.

Distance to field margin

For the analysis of distance to field margin and abundance of thrips nymphs we excluded two fields from the 2020 dataset. One field had such small dimensions that we could only sample at 15 m distance and another field had very delayed and irregular development of the onion plants that we did not consider it to be a representative field.

In both years there is a trend of an increase in number of thrips nymphs (from 30 m) towards the flower margin, except for Wieringerwerf1 in 2020 and Boesingheliede and Slootdorp in 2021 (Figure 2). In 2020 the samples taken at 60 m distance on the field in Middenbeemster and Slootdorp were close to the adjacent crop (grass-clover and grass seed) and may explain an increase of thrips at 60 m distance.

The data indicate that the flower margin may have (partly) acted as a source of *T. tabaci* for most of the sites. It is important to identify the factors that facilitate or inhibit thrips population build-up in the flower margin. The frequently used buckwheat and lacy facelia, for example, seem good hosts for *T. tabaci* (Buckland et al., 2017) and Van den Broek et al. (2011) found indeed more thrips (adult + nymph) in leek next to lacy phacelia or buckweat.

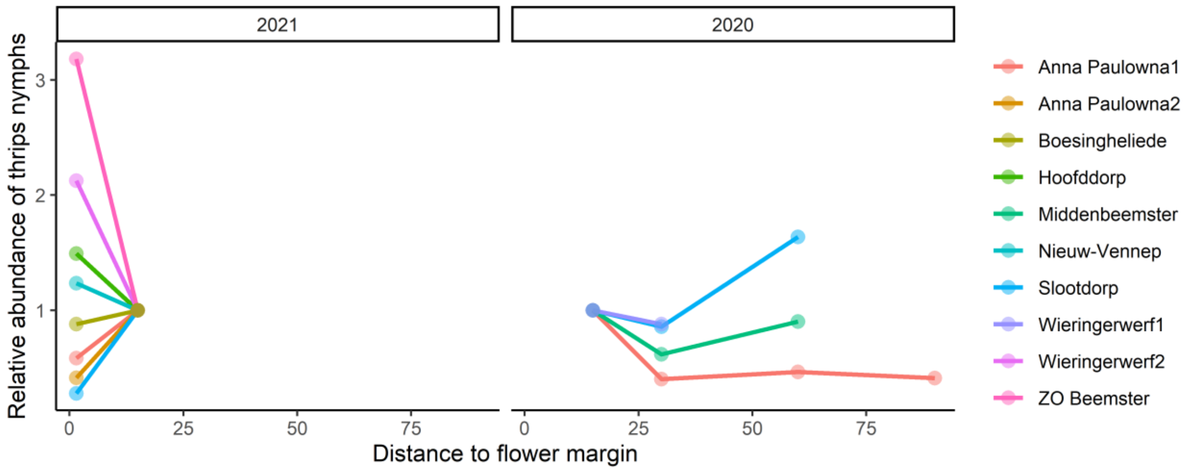


Figure 2. Relative abundance of thrips nymphs at different distances from a flower margin per locality for 2020 and 2021. The relative abundance is the accumulated number of thrips nymphs in the course of the season with total numbers at the 15 m distance set at 1.

Floral composition of the margin

Another factor to take into account is the biocontrol potential of natural enemies of thrips within the strip. At the field in Anna Paulowna different flower strips were sown in the spray tracks and we found more hoverfly larvae in a mixture of lacy phacelia, buckwheat, cornflower and summer cereals (25 larvae) as compared to a strip with only buckwheat (1 larva) or lacy phacelia (2 larvae). A mixture of flower species is preferable over a mono-species margin because it may enhance fitness of hoverfly adults (Rodríguez-Gasol et al., 2020) and survival and performance of their larvae (Amorós-Jiménez et al., 2014).

Conclusion

We found hoverfly larvae as a potential candidate to contribute to thrips control in onion fields. A diverse flower strip that is attractive to hoverflies but not to *T. tabaci* close to the onions at the time when thrips population start to increase is probably an important element for this control strategy to work.

Acknowledgement

We wish to thank all farmers for participating in the monitoring program and lending assistance and a special thanks to Martine Arkema, Roelof Gruppen and Ron Anbergen and the students Adam Elarif and Thomas Brinck for helping to collect the data. The research presented in this paper is co-funded by commercial parties in the Netherlands and the Dutch ministry of Agriculture, Nature and Food Quality (PPS: TU18088).

References

Amorós-Jiménez, Rocco, Pineda, Ana, Fereres, Alberto, and Ángeles Marcos-García, M. 2014: Feeding preferences of the aphidophagous hoverfly *Sphaerophoria Rueppellii* affect the performance of its offspring. BioControl 59(4): 427-435.

Buckland, K. R. et al. 2017: Trap crops in onion to reduce onion thrips and Iris Yellow Spot Virus. Southwestern Entomologist 42(1): 73-90.

Ibrahim, N. D. and Adesiyun, A. A. 2010: Effect of rainfall in the control of onion thrips, *Thrips tabaci* Lindeman (Thysanoptera :Thripidae) in Sokoto, Nigeria. Agriculture and Biology Journal of North America 1(3): 377-386.

Rodríguez-Gasol, N., Alins, G., Veronesi, E. R. and Wratten, S. 2020: The ecology of predatory hoverflies as ecosystem-service providers in agricultural systems. Biological Control 151(February). https://doi.org/10.1016/j.biocontrol.2020.104405.

Rojo, S. et al. 2003: A World Review of Predatory Hoverflies (Diptera, Syrphidae: Syrphinae) and Their Prey. Alicante, Spain: CIBIO Ediciones.

van Alebeek, F. et al. 2009: Rapportage LTO FAB II 2009. https://edepot.wur.nl/154676.

van den Broek, R., Verstegen, H., Gruppen, R. and Kamstra, J. H. 2011: Biologische tripsbeheersing in prei 2008-2010. https://edepot.wur.nl/182088.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 6-10

Floral enhancements and UV-mulch tend to reduce the number of flower thrips and their associated damage in intensive strawberry production

Louis Sutter[1], Virginie Dekumbis[1], Dylan Maret[1], André Ançay[1], Bastien Christ[1]
[1]*Agroscope, Plant-Production Systems, Route des Eterpys 18, 1964 Conthey, Switzerland*

Abstract: Floral enhancements are increasingly present in agri-environmental programmes worldwide. They aim to promote biodiversity and ecosystem services. In the present study, we investigated whether sown wildflower strips and companion plants reduce the abundance and associated damage of flower thrips (FT) in strawberry production. In a replicated on-farm experiment, flower strips tended to reduce the abundance and associated damage of FT on strawberry, whereas companion plants increased the FT associated damage. Damage levels next to companion plants were acceptable, only in combination with repellent UV-mulch. The targeted use of such agroecological interventions provide fundamental resources for natural enemies of crop pests, without posing major environmental risks and could contribute significantly to effective integrated pest management.

Key words: Ecological intensification, flower strip, *Frankliniella* sp., *Orius* sp., push-pull

Introduction

Flower thrips (FT) are polyphagous pests with a short life cycle and high fecundity and in consequence are considered one of the most damaging insect pests in covered crop production worldwide (Reitz, 2009). FT cause malformations and discolorations to leaves, flowers and fruits and are important vectors of plant viruses. FT are difficult to control because of their cryptic life cycle and rapid development of resistance to different classes of insecticides. Consequently, FT are one of the major pests of strawberry production. Adult and immature FT feeding on strawberry blossoms and green berries cause the stigmas and anthers to turn brown and wither prematurely, causing considerable economic losses. (Linder et al., 1998). Currently only a few insecticidal compounds are registered and reports of resistance are of concern and call for sustainable, ecological friendly solutions for the control of these pests.

There are several potential FT control agents which naturally occur in the field or around production sites (Mouden et al., 2017). Recent research has shown that flowering enhancements can increase the abundance of pest control agents as well as pest control. Push-pull strategies were proposed to reduce colonisation of FT through micro-habitat management (Steiner et al., 2011). Ultraviolet reflective mulch foil (UV-mulch) below the crops are also reported to be a repellent for some FT species (Tyler-Julian et al., 2018). Changes in light, temperature and humidity are also likely to affect the behaviour of the pest.

Fostering biodiversity in agricultural landscapes could also be beneficial through provision of ecosystem services. Diverse functional groups of arthropods may provide increased ecosystem services, but due to a reduction in biodiversity of arthropods, cropping systems have experienced a reduced ability to autonomously regulate pests.

Therefore, we looked at the potential effect of sown flower strips, companion plants and UV-mulch on the abundance of FT and their associated damage, to find sustainable control mechanisms.

Materials and methods

Study area and flower strips

This study was conducted in the southern part of Switzerland, the Rhone valley, a region characterized by intensive fruit production. In collaboration with a farmer network, seven flower strips were established near to commercial strawberry (*Fragaria* × *ananassa* variety 'Vivara') tunnels. The flower strips were sown with wildflower species (*Lobularia maritima, Medicago sativa, Phacelia tanacetifolia, Anethum graveolens, Coriandrum sativum, Malva neglecta, Calendula officinale, Trifolium pratense, Fagopyrum esculenteum*) selected based on existing literature. The climate during the vegetative period was colder and wetter than usual, and consequently the establishment of the flower strips was particularly difficult. From the initially planned 12 strips, only 7 (the final set analysed here) established well. To look at the effects of these flower strips on FT abundance and damage over the entire season, the number of FT on strawberry flowers and FT associated damage were monitored in the row nearest to the strawberries (1-2 m away) and on the central row (18-35 m) of the investigated field. The number of FT was monitored weekly by tapping 30 strawberry flower heads per row on a white tray where they were counted by eye. Approximately every two weeks (depending on climate and as a consequence, duration of fruiting cycle) 30 ripe fruit where harvested and damage by FT was assessed (number of damaged fruits divided by the number of harvested fruits = % of damaged fruits).

Phytometer experiment

To test for an effect of companion plant and UV-mulch in each production site, 8 grow bags were used. Two bags were attributed to one of the following treatments: Control = only strawberry plants, CP = companion plant (2 pre grown plants of radish (*Raphanus sativus*) were planted next to strawberry plants). UV = the substrate bags were covered with a UV-mulch (Metalized Plastic Mulch, Dubois AG reported to reduce colonisation by FT *(Tyler-Julian et al.*, 2018, van Toor et al., 2004)). The fourth treatment was the combination of UV and CP = UV/CP. During 8 weeks of the growing season, the FT abundance on flowers and damage on fruits was determined with the above mentioned method, with the modification that all flowers and fruits per growing bag were assessed and not a fixed number. As the effect of the flower strips was very weak for the phytometer experiment, only results of the factors CP and UV and its combination are presented here, even though the phytometer plants were disposed spatially to analyse effect of the flower strip.

Statistical analysis

To test for an effect of the flower strips on FT abundance and damage two ANOVA's with abundance respectively damage were run comparing the two distances from the flower strip. To test for an effect of companion plants, the UV-mulch and its combination (phytometer experiment) on FT abundance and damage two ANOVA's with abundance respectively damage as response values and the treatment as grouping factor were run. As the true replicates in this experiments were the different fields with flower strips, the number of replicates was N = 7. As the overall ANOVA of the phytometer experiment did not show a significant difference over all groups, no post hoc tests were performed to compare differences between group levels.

Results

Influence of flower strip on FT abundance and associated damage

FT abundance on strawberry flowers tended to be lower close to flower strips in comparison with control plots (0.69 vs 0.71 FT per flower, Figure 1 A) although this difference was not significant ($F_{(1,7)} = 1.744$, $P < 0.257$). The results for the FT associated damage were very similar (Figure 1 B) with 38% damaged fruits near to the flower strips versus 49% in the control ($F_{(1,7)} = 3.562$, $P = 0.073$).

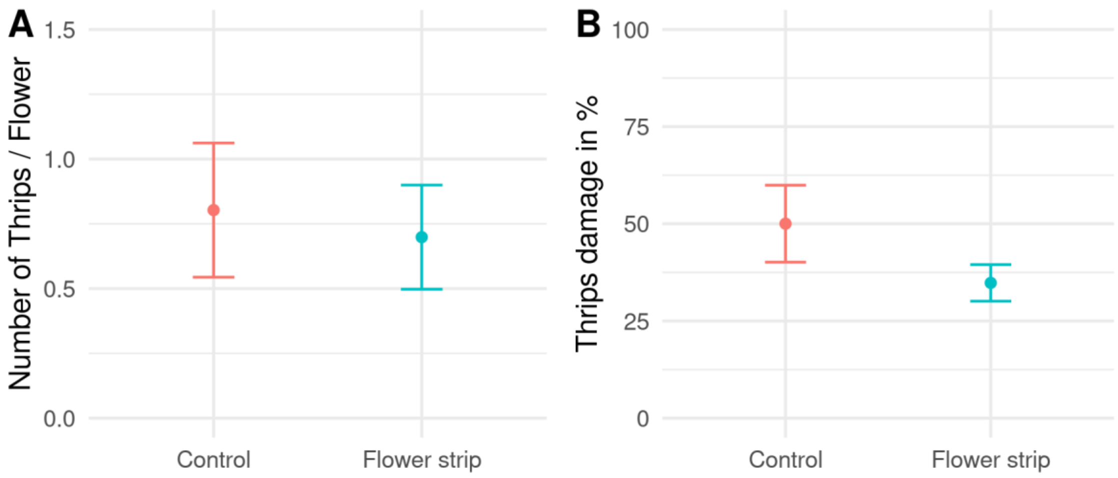


Figure 1. (A) Mean (± 1 standard error) number of FT per strawberry flower in control rows and rows next to flower strip, (B) Mean (± 1 standard error) percentage of damaged strawberries in control rows and rows next to flower strip.

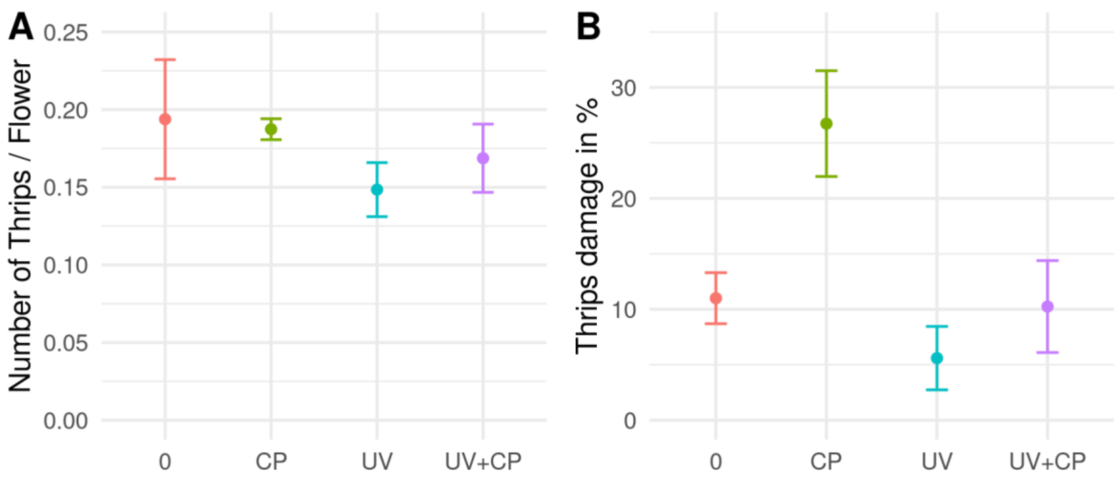


Figure 2. (A) Mean (± 1 standard error) number of FT per strawberry flower, (B) Mean (± 1 standard error) percentage FT associated damage per strawberry in grow bags attributed to the four following treatments: 0 = Control = only strawberry plants, CP = companion plant. UV = substrate bags covered with a UV-reflecting mulch and UV + CP the combination of the two treatments.

Influence of UV-mulch and companion plants on abundance of FT and associated damage
There was no clear trend with no treatment significantly affecting the number of FT found on strawberry flowers ($F_{(3,7)} = 0.022$, $P < 0.873$) (Figure 2A) or fruit damage ($F_{(3,7)} = 1.444$, $P < 0.233$). Surprisingly, when looking at the FT associated damage for the four treatments, it appears that companion plants increased the FT associated damage (11 % in control vs. 26 % in CP treatment). Furthermore, UV mulch seemed to slightly reduce FT associated damage.

Discussion

The results highlight challenges of appropriate scale and attractiveness of flower enhancements, tailored for biological pest control. Flower strips bordering the crop rows tended to reduce the number of pests and their associated damage, whereas companion plants within the crop increased damage of FT markedly.

In agreement with recent case studies and meta-analyses the flower strips tested here tended to contribute to pest control, even though the contribution was not very strong. It remains challenging to have optimal floral resources near the crop to sustain pest control agents at the appropriate period. The ecological quality of the flower strips across the different study sites was very mixed. The challenge of optimal implementation of such wildflower strips in perennial cropping systems remains to be addressed.

The phytometer experiment showed very mixed results and is an example of suboptimal targeting of the flower enhancements. On subsampling of the companion plants, it became clear that they were a temporary reservoir for FT, as population density in these flowers was very high (data no shown). Even though a transfer to the strawberry flower is not evident (Figure 2 A) it is hypothesised that FT harboured in the companion plants increased the damage on nearby strawberry flowers. The climate during the vegetative period was colder and wetter than usual and the abundance of FT in comparison to other years was relatively low. This is an additional reason why some flower strips were difficult to establish and abundance patterns of FT not clear.

Our study demonstrates that wildflowers strips can reduce FT abundance and damage, but also that this effect is strongly dependent of the ecological quality (e. g. flower abundance) of the floral enhancement. It further highlights the urgency of identifying the key factors responsible for this variability and the effectiveness of different types of flower plantations for biological pest control. Based on this better understanding, the design, implementation and management of flower plantations can increase their effectiveness in agri-environmental programmes. This knowledge offers promising avenues for optimising the flower mix to contribute more effectively to the provision of ecosystem services and the ecological intensification of agriculture in the future.

Acknowledgements

We thank all fruit growers involved in the project for providing help to set up the flower strips and their participation in the project.

References

Linder, C., Terretaz, R., Antonin, R. and Mittaz, C. 1998: Les thrips des fraisiers en Suisse romande. Rev. Suisse Vitic. Arboric. Hortic. 30: 161-166.

Mouden, S., Sarmiento, K. F., Klinkhamer, P. G. and Leiss, K. A. 2017: Integrated pest management in western flower thrips: past, present and future. Pest Man. Sci. 73: 813-822.

R Core Team 2021: R: A Language and Environment for Statistical Computing.

Reitz, S. R. 2009: Biology and Ecology of the Western Flower Thrips (Thysanoptera: Thripidae): The Making of a Pest. Flo. Ento. 92: 7-13, 7.

Steiner, M. Y., Spohr, L. J. and Goodwin, S. 2011: Relative humidity controls pupation success and dropping behaviour of western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). Austr. J. of Ento. 50: 179-186.

Tyler-Julian, K., Funderburk, J., Srivastava, M., Olson, S. and Adkins, S. 2018: Evaluation of a Push-Pull System for the Management of *Frankliniella* Species (Thysanoptera: Thripidae) in Tomato. Insects 9: 187.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 11-15

Intra- and inter-specific cues for the management of *Bagrada hilaris* in caper bush cultivations

Salvatore Guarino[1], Mokhtar Abdulsattar Arif[2], Stefano Colazza[3], Ezio Peri[3]
[1]Institute of Biosciences and Bioresources (IBBR), National Research Council of Italy (CNR), Corso Calatafimi 414, 90129 Palermo, Italy; salvatore.guarino@ibbr.cnr.it; [2]Plant Protection Directorate, Ministry of Agriculture, Baghdad, Iraq; mokhtar.a.arif@gmail.com; [3]Department of Agriculture, Food and Forest Sciences, University of Palermo, Viale delle Scienze, Building 5, 90128 Palermo, Italy; ezio.peri@unipa.it; stefano.colazza@unipa.it

Abstract: This paper summarizes the advances in the last ten years about the semiochemicals involved in intra-specific and inter-specific communication of *Bagrada hilaris*, an invasive stink bug damaging the caper bush on the island Pantelleria, Italy. The identification of the chemical cues regulating the behavior of this pest at intra-specific and inter-specific level can give the opportunity for new strategies for its management. The intra-specific communication studies on this species showed that (*E*)-2-octenyl acetate is a major volatile compound emitted by adults. Laboratory bioassays showed that this compound elicit attraction toward *B. hilaris* females and nymphs. A field experiment using double-funnel traps confirmed this response, however, the low number of captures recorded discourage the use of such lure for monitoring purposes. Inter-specific semiochemicals play an important role in the attraction of *B. hilaris* toward its favourite hosts: seedlings of brassica plants at cotyledon-stage. In particular, the attraction seems mainly mediated by brassicadiene an uncommon diterpene, emitted by the most susceptible species as *Brassica oleracea* var botrytis. Field experiments using seedlings of brassica plants as source of attraction showed to have potential as a trap crop for the painted bug to protect caper fields.

Key words: *Capparis spinosa*, painted bug, (*E*)-2-octenyl acetate, brassicadiene, diterpene hydrocarbon, *Brassica oleracea* var botrytis

Introduction

Capparis spinosa L. (Brassicales: Capparaceae), the caper bush, is a perennial plant occurring in environments with dry summer climates, and is typical of the islands of the Mediterranean Basin (Sozzi, 2011). In Italy, caper bush is often cultivated in Sicily and its minor islands on marginal lands. In these conditions caper culture has higher profit margins compared to other local crops. On Pantelleria island caper flower buds have been granted a protected geographical indication by the EU. However, caper bush farming is hampered by a key pest, *Bagrada hilaris* (Heteroptera: Pentatomidae), also known as the painted bug. The painted bug is an invasive species originating from of Asia, which feeds on brassicaceous crops (Palumbo et al., 2016). After its accidental introduction in 1978, *B. hilaris* progressively extended its area on the island and caused increasing economic damage to caper crops (Colazza et al., 2004). To control painted bug populations, caper growers have relied on the use of chemical insecticides (Guarino et al., 2007). In this context, new tools for the management of *B. hilaris* populations have been considered in order to reduce treatment costs, develop non-chemical control options and give caper growers the opportunity to switch to organic agriculture. For this puprose, studies have explored the potential of volatile stimuli involved in the chemical communication of this pest at intra- and inter-specific level, in order to have attractant that might be positively exploited for monitoring and controlling *B. hilaris*. The objective of this review is to show the recent advances in the knowledge of the chemical ecology of *B. hilaris* and their field application for painted bug population management in caper cultivations of Pantelleria island.

Intra-specific semiochemicals

The first studies on the chemical ecology of painted bug carried out by De Pasquale et al. (2007) and Guarino et al. (2008) revealed the role of contact and volatile cues in the mating behavior of *B. hilaris*. These studies showed that (*E*)-2-octenyl acetate is the main compound produced by painted bug adults, with significantly higher amounts emitted by males in comparison with females, suggesting that it may function as a sex pheromone. Further studies carried out by Arif et al. (2020 a) evidenced that (*E*)-2-octenyl acetate evokes stronger electroantennogram responses in *B. hilaris* females than in males or nymphs (Figure 1 A). The same research confirmed that this molecule elicits stage specific responses. In olfactometer experiments females were attracted to (*E*)-2-octenyl acetate, both in presence or absence of a host plant (i. e. *Brassica oleracea* seedlings), while nymphs shower attraction only in presence of the host plant, and males showed no attraction in both conditions (Figures 1 B and 1 C).

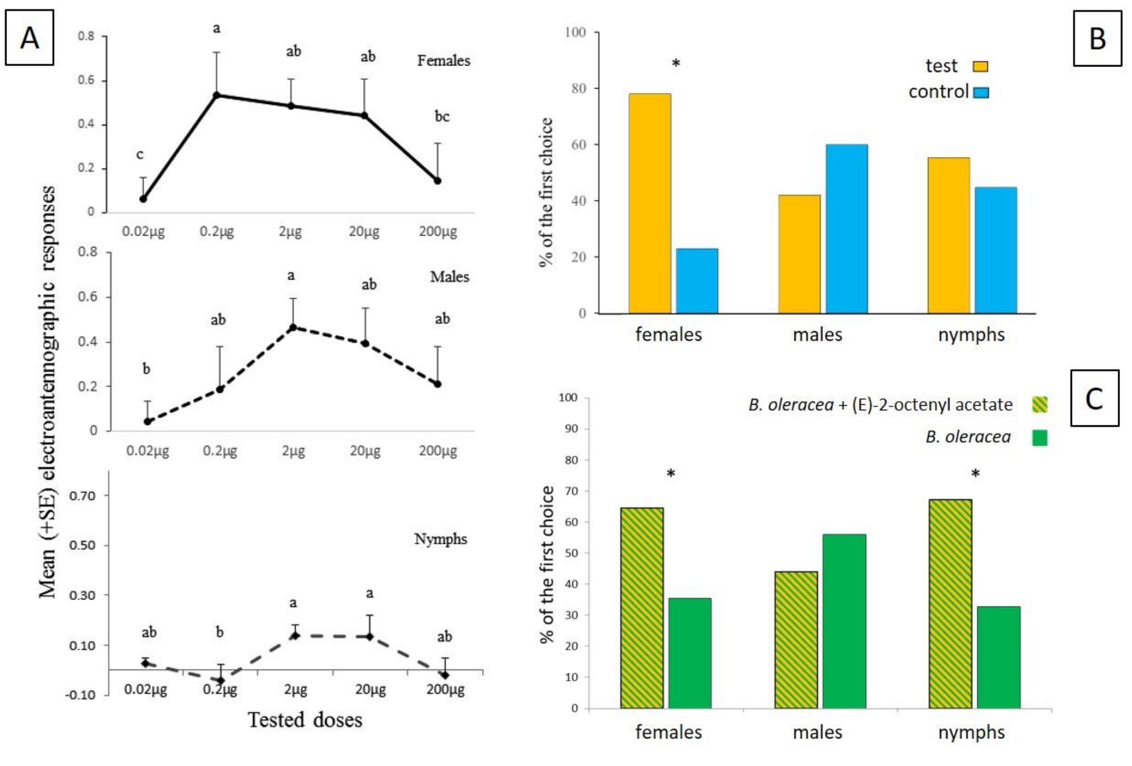


Figure 1. A: EAG dose–response curves of *Bagrada hilaris* to (*E*)-2-octenyl acetate. Different letters indicate that values differ statistically at P < 0.05, ANOVA, LSD test. B: Response of *B. hilaris* to (*E*)-2-octenyl acetate (test) and to solvent (control). C: Response of *B. hilaris* to (*E*)-2-octenyl acetate in presence of *B. oleracea* seedlings versus *B. oleracea* seedlings alone. * = P < 0.05, χ^2 (Arif et al., 2020 a).

Albeit these laboratory results were promising, field test only partially confirmed these responses. In fact, the use of (*E*)-2-octenyl acetate in field bioassays using double-funnel horizontal plastic traps resulted in a low level of captures, and only in trap loaded with 5 and 10 mg of (*E*)-2-octenyl acetate (Arif et al., 2020 a). So even though (*E*)-2-octenyl acetate functions as a *B. hilaris* pheromone, attracting both females and nymphs, the weak attraction observed in the field tests suggests that more reasearch is needed to exploit this attractant for monitoring purposes.

Inter-specific semiochemicals

Studies focussing on the interaction of *Bagrada hilaris* with their host plants showed that *B. hilaris* has a preference for specific vegetables and specific phenological growth stages. In particular, brassica cotyledon-stage seedlings are susceptible to *B. hilaris* attack. Joseph and co-workers (2017) observed that *Eruca sativa* seedlings are very attractive for *B. hilaris*. A study by Guarino et al. (2018) documented the preference of *B. hilaris* adults for seedlings of *B. oleracea* var. botrytis and *B. napus* in comparison with other species, such as *B. carinata*. This study revealed that the attraction is mediated by a diterpene hydrocarbon, brassicadiene (Arriola et al., 2020), dominating the seedling volatile emission of the most susceptible species (Guarino et al., 2018). To exploit such sources of attraction for management purposes, Arif et al. (2020 b) evaluated seedlings of *B. oleracea* and *E. sativa* as candidates for a trap crop for caper cultivation on Pantelleria island to reduce *B. hilaris* infestations. Testing these species as lures inside double-funnel traps in field experiments showed that *B. oleracea* and *E. sativa* seedlings can attract a notable number of *B. hilaris* individuals in the traps (Figure 2) (Arif et al., 2020 b). In a further field test, the seedling were sown in artificial pots, and after emergence placed in a caper field infested by *B. hilaris* to test their ability to attract and divert painted bug individuals from caper bushes (Arif et al., 2020 b). These results indicated that *B. hilaris* individuals were effectively distracted from caper bushes and attracted to the seedlings pots loaded with *E. sativa* and *B. oleracea* seedlings (Table 1).

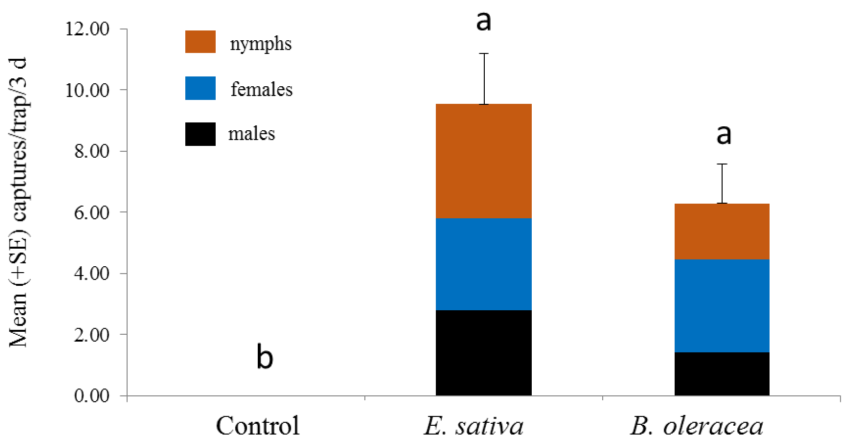


Figure 2. Mean (+ SE) *Bagrada hilaris* individuals captured in horizontal traps lured by *Brassica oleracea* and *Eruca sativa* seedlings or control traps. Different letters indicate that values differ statistically at P < 0.05 (ANOVA, Tukey test) (Arif et al., 2020 b).

Table 1. Mean (+ SE) *Bagrada hilaris* individuals observed per pot with cotyledon-stage seedlings of *Eruca sativa*, *Brassica oleracea* and *Brassica carinata* per day (Arif et al., 2020 b).

Days from emergence	3	5	7	9	11	13	15
Eruca sativa	20.33 ± 12.81	114.00 ± 86.66	187.33 ± 68.89	131.33 ± 84.82	148.00 ± 96.02	49.66 ± 49.60	26.00 ± 22.00
***Brassica oleracea* var botrytis**	2.00 ± 1.15	11.00 ± 5.50	66.00 ± 17.34	194.66 ± 96.32	225.00 ± 51.81	112.00 ± 38.08	15.00 ± 9.00
Brassica carinata	2.33 ± 1.85	1.66 ± 0.88	23.33 ± 11.66	36.33 ± 19.54	71.00 ± 37.07	51.00 ± 41.00	45.00 ± 15.00

Conclusions

The results obtained in these studies indicate that brassicaceous cotyledon-stage seedlings are good candidates as attractant sources for *B. hilaris* and may find application as a lure or in trap cropping techniques. The use of such tools for painted bug management has promise on Pantelleria island, where caper bush cultivation is widespread and an important source of income for local growers, which increasingly adopt organically management practices. Furthermore, in consideration of the worldwide impacts of *B. hilaris* on agricultural crops, these results can be considered a starting point for implementing the management of this pest more widely.

References

Arif, M. A., Guarino, S., Colazza, S. and Peri, E. 2020 a: The role of (*E*)-2-octenyl acetate as a pheromone of *Bagrada hilaris* (Burmeister): Laboratory and field evaluation. Insects 11: 109-120.

Arif, M. A., Guarino, S., Peri, E. and Colazza, S. 2020 b: Evaluation of Brassicaceae seedlings as trap plants for *Bagrada hilaris* Burmeister in caper bush cultivations. Sustainability 12: 6361.

Arriola, K., Guarino, S., Schlawis, C., Arif, M. A., Colazza, S., Peri, E., Schulz, S. and Millar, J. G. 2020: Identification of brassicadiene, a diterpene hydrocarbon attractive to the invasive stink bug *Bagrada hilaris*, from volatiles of cauliflower seedlings, *Brassica oleracea* var. botrytis. Org. Lett. 22: 2972-2975.

Colazza, S., Guarino, S. and Peri, E. 2004: *Bagrada hilaris* (Burmeister) (Heteroptera: Pentatomidae) a pest of caper in the island of Pantelleria [*Capparis spinosa* L.; Sicily]. Inf. tore Fitopatol. 54: 30-34.

De Pasquale, C., Guarino, S., Peri, E., Alonzo, G. and Colazza, S. 2007: Investigation of cuticular hydrocarbons from *Bagrada hilaris* genders by SPME/GC-MS. Anal. Bioanal. Chem. 389: 1259-1265.

Guarino, S., Peri, E., Lo Bue, P., La Pillo, A. and Colazza, S. 2007: Impiego di insetticidi di origine vegetale per il contenimento delle popolazioni di *Bagrada hilaris* nei cappereti panteschi. Inf. tore Fitopatol. 7: 53-58.

Guarino, S., De Pasquale, C., Peri, E., Alonzo, G. and Colazza, S. 2008: Role of volatile and contact pheromones in the mating behaviour of *Bagrada hilaris* (Heteroptera: Pentatomidae). Europ. J. Entomol. 105(4): 613.

Guarino, S., Arif, M. A., Millar, J. G., Colazza, S. and Peri, E. 2018: Volatile unsaturated hydrocarbons emitted by seedlings of *Brassica* species provide host location cues to *Bagrada hilaris*. PloS one. 13(12): e0209870.

Joseph, S. V., Grettenberger, I. M., Godfrey, L. D. and Zavala, N. 2017: Susceptibility of germinating cruciferous seeds to *Bagrada hilaris* (Hemiptera: Pentatomidae) feeding injury. Arthropod Plant Interact. 11(4): 577-590.

Palumbo, J. C., Perring, T. M., Millar, J. G. and Reed, D. A. 2016: Biology, ecology, and management of an invasive stink bug, *Bagrada hilaris*, in North America. Annu. Rev. Entomol. 61: 453-473.

Sozzi, G. O. 2001: Caper bush: botany and horticulture. Hortic. Rev. 27: 125-188.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 16-20

Carabid beetle community responses to integrated management practices in commercial crops in Fife, Scotland

James Reid-Thomas[1], Gail E. Jackson[1], Cathy Hawes[2]
[1]*Global Change Research Institute, The School of GeoSciences, University of Edinburgh, Edinburgh, EH9 3FF, Scotland;* [2]*The James Hutton Research Institute, Errol Road, Dundee, DD2 5DA, Scotland*
Corresponding author: G.Jackson@ed.ac.uk

Abstract: This study investigated the way in which carabid beetle abundance and species assemblages changed in response to crop type and habitat management. The aim was to better understand the effects of the implementation of agroecological management to support viable carabid populations. A split-field design was used to compare conventional commercial practice with an integrated practice, designed to support carabids. Pitfall traps were used to assess changes in carabid abundance and assemblage between fields. The results showed that carabid occurrence was most strongly determined by crop type and that the effectiveness of management practice varied according to crop type. Carabid response to both crop type and habitat management varied substantially according to carabid species. Key predatory species such as *Nebria brevicollis* showed a preference for cereal crops and oilseed rape and were more abundant in integrated than conventional split-fields. These findings demonstrate that the implementation of management measures, such as under-sowing and planting of field margins, can successfully increase carabid abundance in commercial crops and therefore the potential they have for enhancing natural pest control.

Key words: carabid beetles, pests, integrated control

Introduction

Globally, agriculture is faced with the growing challenge of meeting the food production demands of an increasing world population, whilst also protecting natural resources and maintaining biodiversity levels. To that end, the Centre for Sustainable Cropping (CSC) was set up in 2009 as a long-term experimental platform and research centre at Balruddery Farm, Fife, Scotland (56.48°N, 3.13°W) (Hawes et al., 2016). This study tests the effectiveness of the cropping systems with a focus on Integrated Pest Management (IPM) and protection of biodiversity. Features designed to boost carabid beetle numbers include, planted infield weed understoreys, diversified field margins and beetle banks. This study aimed to determine the extent to which these IPM measures influence carabid abundance and assemblages.

Three explanatory variables were investigated: (i) management type (ii) crop type and (iii) field position. Crop type was anticipated to have the greatest influence on carabid occurrence, because it strongly determines habitat structure and food availability. A growing literature suggests carabids have a preference for under-sown cereals and oilseed rape, over grass and other crop types (Jowett et al., 2021). Carabids' preference for oilseed rape has been linked with the greater number of suitable prey items found in oilseed rape compared with other crops. Carabid preference for under-sown barley and other cereals is a combination of two factors: the benefit of having two canopy layers of vegetation and secondly the greater range of suitable micro-habitat types afforded by nitrogen fixing weeds and grasses in the understorey layer.

The two management measures in place at the CSC aimed at supporting carabids, are tussocky grass margins and in-field weed understoreys. Tussocky grass margins are necessary to maintain a diverse predatory carabid fauna as they provide resources and shelter for carabids at different times of the year, such as when they hibernate in winter. In-field weed understoreys create a more varied canopy structure, which carabids favour. In addition they also create sheltered microhabitats with cooler temperatures and higher humidity, which protect carabids from extreme temperatures and rainfall. Finally, they provide additional animal and floral food resources to support carabid populations.

Most of the carabid species found in agro-ecosystems are polyphagous predators but different species prey on crop pests to varying degrees. It is therefore important to identify carabids at the species level and measure the effects of management on carabid assemblages and community composition (Holland et al., 2005). The main aim of this study is to investigate whether carabid abundance, richness and diversity is increased by integrated rather than conventional management. Additionally the populations within field and within margins is compared and the effects of crop type and field position investigated.

Materials and methods

Study site

The CSC is a 42 ha block of six fields designed to quantify the impact of new cropping systems on a range of variables, including crop yields and species biodiversity. Each field is planted with one crop type but is split into two half fields; one of which is managed conventionally and the other integrated. The fields range in size from 4.26 ha to 7.10 ha, each split evenly between the two treatment types. The mean half field side lengths are 180 m by 90 m. The six crop types are: beans, winter oilseed rape, winter barley, spring barley, potatoes and winter wheat. The crops are grown in a six year rotation. Each integrated half field is surrounded on three sides by 2 m wide wildflower margins and on one side with a 6 m wide beetle bank. Conventional half fields are not surrounded by wildflower margins. The beetle bank buffers are made up of a standard tussocky grass mix and run through the middle of each field, in order to separate the conventional and integrated treatments.

Sampling design

Carabid sampling was carried out every April from 2011 until 2019. Pitfall traps were installed for two, two-week trapping periods, with 168 pitfall traps set out in total across the platform; 14 in each half field. Nine were set along a linear transect in the crop and five along a perpendicular transect in the field margin. Traps were spaced 10 m apart with the first trap of the field transect located approximately 50 m from the field corner. The counts from the two trapping periods were pooled, since they were not independent. The data presented in this paper represents the samples from April 2017 only.

Carabids were identified to species level and classified according to feeding preferences: a) granivorous b) polyphagous predator c) specialised predator. For each trap, species abundance, richness and diversity (Shannon Index) were recorded.

Statistical analysis

Linear mixed models (LMM) and an AIC comparison were used to determine the explanatory power of each of the explanatory variables: i) management type ii) crop type and iii) field position, on carabid abundance, species richness and diversity, as well as on the abundance of individual carabid species and functional groups. All statistical tests were carried out in RStudio (Version 1.4.1717).

Results

Carabid abundance

Carabid abundance was significantly greater in field areas (mean abundance = 7.47 per trap) compared with in margin areas (mean abundance = 2.02 per trap) ($F_{(1,118)} = 31.6$, $p < 0.0001$). Crop type also significantly influenced carabid abundance ($F_{(5,162)} = 15.4$, $p < 0.0001$), with greatest abundance in winter wheat and least abundance in field beans (Figure 1).

There was no significant affect of conventional vs integrated management ($F_{(1,166)} = 1.88$, $p < 0.172$), although there were more carabids in the integrated half-fields compared with the conventional half-fields (integrated abundance = 6.55 per trap, conventional abundance = 5.07).

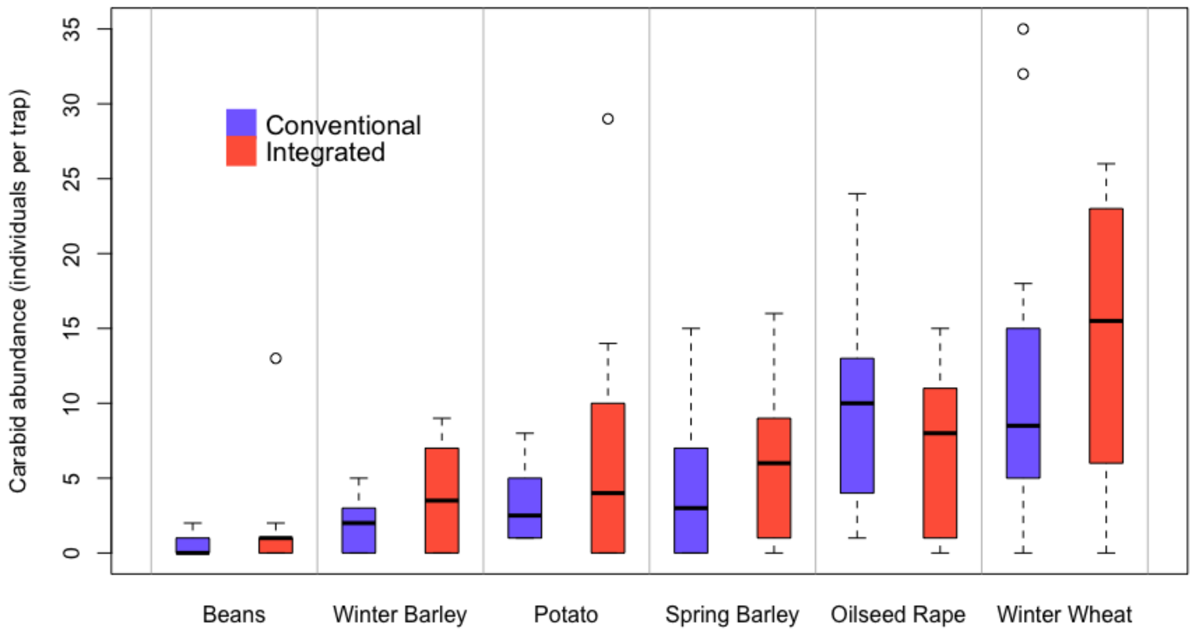


Figure 1. The effect of management and crop type on mean pooled carabid abundance.

Carabid species richness and diversity

Species richness and species diversity were both significantly greater in the crop, than in the margins (Figure 2) ($F_{(1,118)} = 22.80$, $p < 0.001$ and $F_{(1,118)} = 23.94$, $p < 0.0001$, respectively). Species richness and diversity were greater in the cereal crops, than in beans. Conventional versus integrated management had no effect on species richness and diversity.

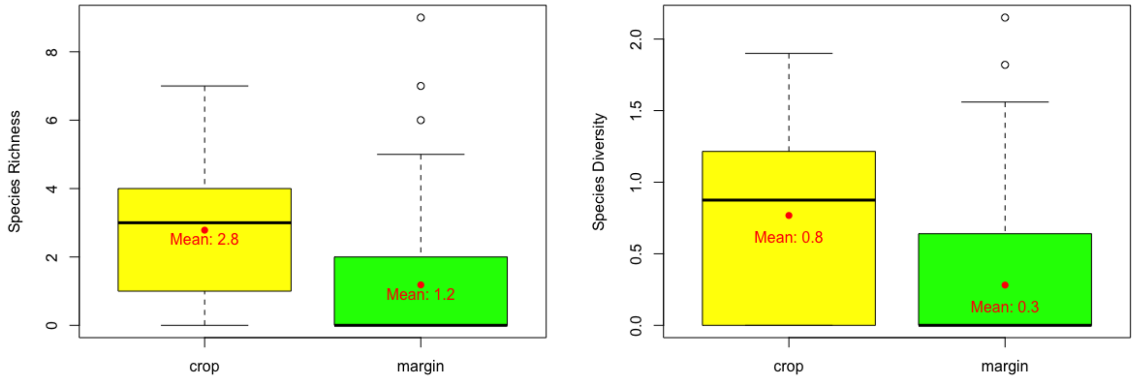


Figure 2. The effect of field position on carabid species richness and species diversity.

The six most common species were *Nebria brevicollis*, *Bembidion lampros*, *Loricera pilicornis*, *Pterostichus strenuus*, *Amara plebeja and Notiophilus biguttatus*, which together accounted for 86 % of all counts (837 out of 976). *Nebria brevicollis* was the most dominant species (46 % of all counts). By functional group, polyphagous predators were the most common (803 of 976 counts), followed by specialised predators (92 of 976 counts), and finally granivores were the least common (81 of 976). Functional group composition was similar between margins and field areas, with the exception that granivores made up a greater proportion of counts in margins than in field areas.

Discussion

Surprisingly the results did not demonstrate the expected increased carabid abundance, species richness and species diversity under integrated compared with conventional management. This could be an effect of the time of year. Sampling took place in April and it may be that the margins and beetle banks would be better utilised at other times of the year. Tussocky margins are commonly used as overwintering grounds for many carabid species and there is still considerable debate in the literature around the timing and extent of migrations between margin and field areas.

The effectiveness of conventional versus integrated management varied according to crop type, suggesting that enhanced natural predation of pests for IPM may only be feasible in certain crop types such as oilseed rape, barley and wheat.

References

Hawes, C., Begg, G. S., Iannetta, P. P. M., Karley, A. J. and Squire, G. R. 2016: A whole-systems approach for assessing measures to improve arable ecosystem sustainability. Ecosyst. Health Sustain. 2(12): p.e01252.

Holland, J., Thomas, C. F. G., Birkett, T., Southway, S. and Oaten, H. 2005: Farm-scale spatiotemporal dynamics of predatory beetles in arable crops. J. Appl. Ecol. 42(6): 1140-1152.
Jowett, K., Milne, A. E., Garrett, D., Potts, S. G., Senapathi, D. and Storkey, J. 2021: Above- and below-ground assessment of carabid community responses to crop type and tillage. Agr. Forest Entomol. 23(1): 1-12.

Session Biodiversity

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 22-25

Role of green manure and bare soil in influencing carabid and slug populations in fields under different management

Augusto Loni[1], Roberto Canovai[1], Daniele Antichi[1,2], Elisabetta Rossi [3]
[1]DAFE – University of Pisa, Via del Borghetto, 80 Pisa, Italy; [2]CiRAA – University of Pisa, Via Vecchia di Marina, 6 San Piero a Grado, Italy; [3]Via Amoa 32c, Arcola, Italy
Corresponding author: augusto.loni@unipi.it

Abstract: The effects on carabid and slug populations of a wintertime green manure in organic management compared to bare soil in low-input conventional management, were assayed in six experimental fields in the nearby of Pisa (Italy). Pitfall traps were placed in three different periods, from November 2015 to June 2016. The captures showed significant differences between the fields with green manure, compared to those with winter fallow, with a higher number of slug (about 99 %) and carabid (about 90 %) of the specimens collected. No differences emerged about the diversity and evenness indeces, showing that the contribution on biodiversity of any agronomic practice is complicate and hard to evaluate, because the complexity of the relationships among organisms and the environmental factors.

Key words: Cover crop, ground beetles, biocontrol

Introduction

Cover cropping is an agronomic practice that supports various ecosystem services in agro-ecosystems. Cover crops can produce positive effects to counteract soil erosion and nutrient leaching, by increasing soil organic matter content and thus supporting soil biota and increasing soil biodiversity (Keesstra et al., 2018). Its contribution on biodiversity of agroecosystems is probably the most complicate aspect to evaluate, because of the complex relationships between the organism population and the environmental factors. Such difficulties are higher in annual crops, where the communities are disturbed by frequent environmental changes due to the crop management. In particular, the analysis involving parasitoids can produce contrasting results (Dumbar et al., 2017). However, grass cover crops act as the most effective habitat for the overwintering of generalist predators, specifically carabid and staphylinid beetles (Collins et al., 2003). In this work, the influence of a winter cover crop, terminated in spring as green manure, on carabid assemblages and slug populations in six fields in the nearby of Pisa, at San Piero a Grado (Tuscany, Italy), was assayed.

Materials and methods

The experimental fields were chosen within MASCOT trial (Barberi and Mazzoncini, 2006) a long-term agronomic trial started in 2006 and still ongoing, focusing on the comparison of organic and conventional management systems.The survey was carried out in three time intervals, each sampling period of 2 or 4 weeks, between November 2015 and April 2016 (06-27 November 2015 I; 04-11April 2016 II; May 25th - June 08th 2016 III), on six rectangular fields of approximately 1 ha of surface (30 × 300 m) each. Three fields were under organic management and three under conventional management. Organic fields were supplied with organic manure whereas the conventional ones with mineral fertilizers. The weed control was mechanical in the organic system and chemical in the conventional system (post-emergence herbicides). The main and secondary tillage methods were the same for both systems (Mazzoncini et al., 2015). In the years 2015 and 2016, in the organic fields, a mixture of hairy vetch (*Vicia villosa* Roth.) and barley (*Hordeum vulgaris* L.) was grown as a green manure in the period between November 2015 and June 2016; in the same period, the conventional fields were kept bare. From 25 May to 8 June, sunflower (*Helianthus annuus* L.) was sown on 6 fields each. Eight pitfall traps were placed in a hypothetical center line of each field, covering the entire surface. They were baited with a solution of 250 ml of vinegar and 10 g of sodium chloride. Carabids were collected weekly in each period and stored in 70 % ethanol until their classification, carried out at species level with the specific keys for the Italian carabids (Brandmayr et al., 2005; Pesarini and Monzini, 2010 and 2011). Slug samplings were performed with eight commercial mat traps aligned in the middle of each field, adjacent to the pitfall traps. Slug classification was carried out at family level to correlate their abundance to that of carabids. The number of species and the total specimens were compared in both organic and conventional fields; we also calculated the Shannon-Wiener (H') and the Pielou's (J') eveness indexes. The ordination principal coordinates analysis (PCO) has been produced, and the potential relationships among the sets variables (species) and the ordination axes was performed by overlaiyng the vectors of the most represented species onto the axes (Anderson et al., 2008).

Results and discussion

Organic fields totalized 2628 carabid specimens vs 334 of conventional ones. *Poecilus cupreus* (L.) resulted the most abundant species in both organic and conventional fields, with a huge concentration during the second period in the organic ones (2016 vs. 213), coinciding with the higher presence of slugs (165 vs. 1). Apart from *P. cupreus*, only *Nebria brevicollis* (Fabricius) and *Pterostichus melas* Dejean reached more than hundred specimens. *Pseudophonus rufipes* (De Geer), *Distichus planus* (Bonelli), *Pterostichus niger* (Schaller), *Notiophilus substriatus* Waterhouse, *Calathus circumseptus* Germar were represented with at least 25 specimens. The remaining species counted less than 20 specimens. Twelve species represent singleton or doubletone captures. The complete list of carabid species will be published in a further paper. Table 1 lists for each sampling period the number of captures and species of carabids and the number and slugs. PCO ordination produced a clear separation between the projections of organic and conventional samples on the main axis. The organic samples show a very high spatial proximity of all samples, describing an higher within-similarity, respect to the samples of conventional fields (Figure 1). The diversity and evennes index resulted higher in the conventional fields than in the organic ones. Organic fields hosted a larger carabid populations in terms of abundance and a greater number of species (Table 2). The peak of *P. cupreus* in the organic fields, observed in the second period of sampling, presumably biased the calculation of H' and J'. In this period, an elevated presence of slugs was observed on the barley-vetch mixture in organic fields (see Table 1) and this reasonably could have caused the peak of *P. cupreus*, which is a generalist predator, whose predatory activity on slugs and their eggs is well known (Oberholzer and Frank, 2003).

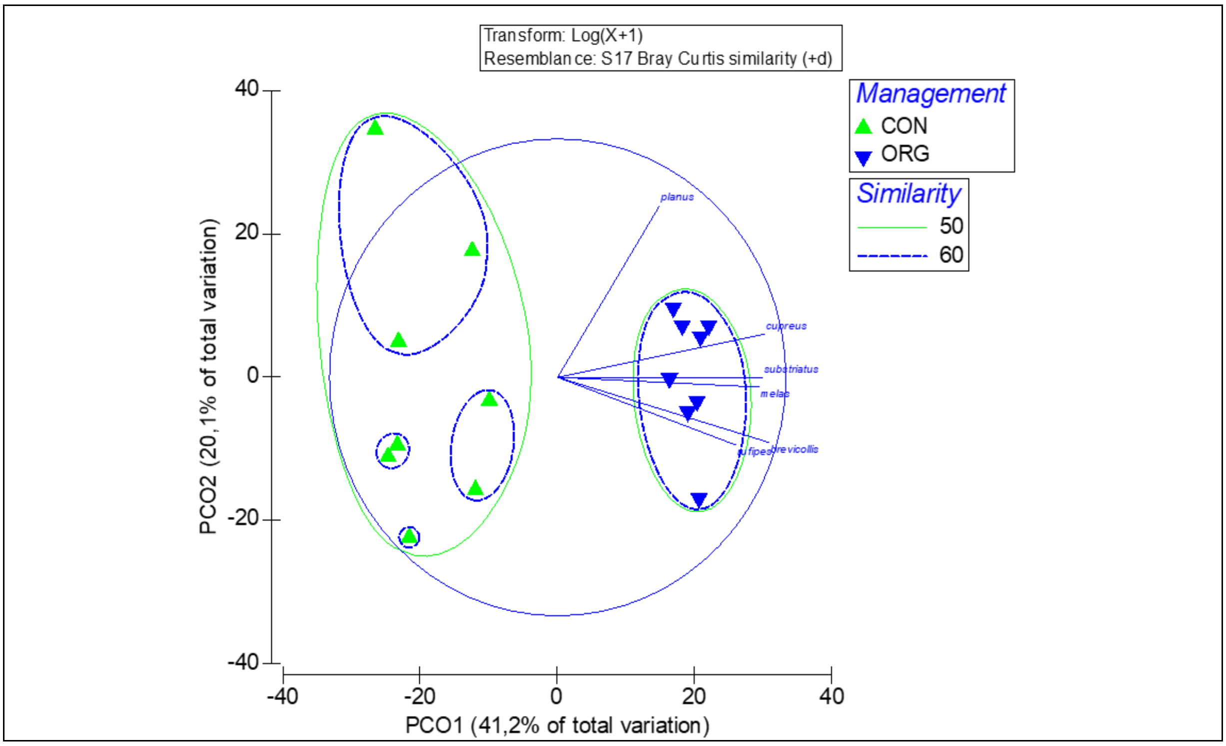


Figure 1. PCO on data of trap samples obtained in the fields under the two management systems.

Table 1. Number of carabid specimens and species, and number of slug specimens captured in the organic and conventional fields during the sampling periods. * Some species are shared among different period and the total number does not match with the sum of the periods.

Periods of samplings	Carabid specimen number			Carabid species number			Slug specimen number	
	Management		Total	Management		Total	Family Limacidae / Milacidae / Arionidae	
	Org	Con		Org	Con		Org	Con
I	432	91	523	20	16	25	5 / 20 / 11 (36)	0
II	2136	224	2360	18	4	18	153 / 1 / 11 (165)	1 / 0 / 0
III	60	19	79	9	5	9	2 / 0 / 1 (3)	1 / 0 / 0
Total	2628	334	2962	33*	22*			

Among the agroecosystems, extensive crops have the most simplified and ephemeral ecological structures. Being frequently manipulated and managed by humans, ecological balances in such agroecosystems are difficult to establish and a community of insects can hardly achieve a stable balance. Such ecological situation emerges from the data, nevertheless the cover crops act as one of the most effective habitats for the overwintering of generalist predators specifically carabid and staphylinid beetles (Collins et al., 2003). Cover crops represent a useful habitat for a rich overwintering population of predators but also of their preys (i. e., slugs).

Nevertheless, terminating the cover crop in spring as a green manure (e. g. by crushing and disk harrowing the cover crop biomass, as in the present study) can result in avoiding any economical loss due to the feeding activity of slugs on the following cash crops. The number of slugs in the spring-sown cash crop can be indeed drastically reduced with the tillage operations.

Table 2. Shannon-Wiener and Evenness indexes for carabids captures in organic and conventional fields.

SAMPLE	S	N	J'	H'(loge)
O	33	2628	0.23	0.99
C	22	334	0.5	1.57

S = number of species; N = number of specimens; J' = Pielou's evenness; H' = Shannon Biodiversity Index

References

Anderson, M. J., Gorley, R. N. and Clarke, K. R. 2008: Permanova + for Primer: guide to software and statistical methods. PRIMER-E, Plymouth, United Kingdom.

Bàrberi, P. and Mazzoncini, M. 2006: The MASCOT (Mediterranean Arable Systems Comparison Trial) long-term experiment (Pisa, Italy). In: Raupp, J., Pekrun, C., Oltmanns, M. and Köpke, U. (eds.): Long-term field experiments in organic farming. ISOFAR Scientific Series, Verlag, Berlin (DE): 1-14.

Brandmayr, P., Zetto, T. and Pizzolotto, R. 2005: Coleotteri Carabidi per la valutazione ambientale e la conservazione della biodiversità. Manuale operative 34: 151-185. APAT, Roma, Italy.

Collins, L. K., Boatman, N. D., Wilcox, A. and Holland, J. M. 2003: Effects of different grass treatments used to create overwintering habitat for predatory arthropods on arable farmland. Agriculture, Ecosystems and Environment 96: 59-67.

Dunbar, M. W., Gassmann, J. A. and O'Neal, M. E. 2017: Limited Impact of a Fall-Seeded, Spring-Terminated Rye Cover Crop on Beneficial Arthropods. Environmental Entomology 46(2): 284-290.

Keesstra, S., Mol, G., de Leeuw, J., Okx, J., de Cleen, M. and Visser, S. 2018: Soil-related sustainable development goals: four concepts to make land degradation neutrality and restoration work. Land 7(4): 133.

Mazzoncini, M., Canali, S., Giovannetti, M., Castagnoli, M., Tittarelli, F., Antichi, D., Nannelli, R., Cristani, C. and Barberi, P. 2010: Comparison of organic and conventional stockless arable systems: a multidisciplinary approach to soil quality evaluation. Appl. Soil Ecol. 44: 124-132.

Oberholzer, F. and Frank, T. 2003: Predation by the Carabid beetles *Pterostichus melanarius* and *Poecilus cupreus* on slugs and slug eggs. Biocontrol Sci. Techn. 13: 99-110.

Pesarini, C. and Monzini, V. 2010: Insetti della fauna italiana. Coleotteri Carabidi I. Natura 100: 3-152.

Pesarini, C. and Monzini, V. 2011: Insetti della fauna italiana. Coleotteri Carabidi II. Natura 101: 3-144

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 26-29

Bee diversity and plant pollinator relationship in the city of Milan

Alessandro L. Heinzl[1], Carla Sorvillo[1], Debora Voltolina[2], Serena Malabusini[1], Simone Sterlacchini [2], Daniela Lupi [1]
[1]University of Milan, Defens, Via Giovanni Celoria, 2, 20133 Milano, Italy; [2]CNR – IGAG - National research council, Piazza della Scienza,1, 20126 Milano, Italy

Abstract: Urban environment is an uncertain suitable habitat for bees and particularly for wild bees. In this work we analyse the relationship between the urban green areas and its plants with wild bees (Hymenoptera: Apoidea: Apiformes) in the city of Milan, northern Italy.

Key words: wild bee, Apoidea pollinators, urban environment, conservation, pollination network, modelling

Introduction

Apiformes Hymenoptera are among the most fragile insects subject to a worldwide decline in species richness and abundance (Sànchez- Bayo and Wyckhuys, 2019). According to different studies, this decline is due to several causes and the main to be mentioned are: agricultural intensification, habitat alteration (including urbanization), use of pesticides, and climate change (Sànchez-Bayo and Wyckhuys, 2019; Isawaki, 2017). However, the role of urbanisation is doubtful (Banaszak-Cibicka and Zmihorski, 2012; Fischer et al., 2016), especially in more developed countries where cities provide a major variability in plant and flowers species, nesting sites and nest building materials, associated with a limited use of pesticide (Fischer et al., 2016). The presence of these positive aspects varies widely among cities due to geographical, historical, social, economic factors (Banaszak-Cibicka, 2016; Baldock et al., 2019) and can be differently influenced by organism interactions in the environment (Theodorou et al., 2020, Balbock et al., 2015, Jones and Leather, 2012).

Italy is one of the European countries characterized by the highest species richness (Nieto et al., 2014). However, the outdated information related to the presence, distribution, and life cycle of Italian wild bees do not allow to know their conservation status in the Country (Quaranta, 2018).

To increase the knowledge on Italian bees, a triennial study has been performed in the city of Milan, northern Italy (45°28′01″N 9°11′24″E), distributed on an area of 181,68 km^2 covered for 13.76 % by green areas. The aims of this research are to update the checklist of bees in the city of Milan, to investigate the interaction of bees with the plants used for recreational purposes, and, finally, to locate and predict the most suitable areas for Apoidea through the data driven Bayesian weight of evidence model.

Materials and methods

Study area

The city of Milan (45°28′01″N, 9°11′24″E) currently has more than half a million trees planted in its 2,500 hectares of public green areas in the municipality. The total public green space is composed by different kind of greenery; peri-urban park (37 %), urban park (12 %), historical park (4 %), neighbourhood garden (28 %), public garden (18 %), and green road, including roundabouts and tree rows (Comune di Milano, 2008; Lassini et al., 2014). Each type of green category differs from the others by the position in the city, the extension, the management, the fruition, the composition of plants, and the presence of infrastructure.

Sampling and identification

To represent the different greenery, 90 green areas have been selected; 11 neighborhood gardens, 11 public gardens, 3 periurban parks, 4 historical parks, 3 urban parks, and 58 green roads. Monitoring was carried out over 3 years (2019-2021); from June to September 2019; from February to July 2020; from March to October 2021. In each area, all flowered plants were monitored at each visit and observations of 5 minutes were conducted in plot subsets on each plant species to detect bees feeding on flowers. When an interaction was observed it was noted together with the food source selected by the bee (nectar/pollen). The classification was made at the lowest taxonomical level possible (species/genera) either in field, if possible, or in laboratory (after collection of the specimen, its conservation in freezer and preparation). A fillable form created with KoBo Collect/Toolbox (https://www.kobotoolbox.org/) was used for data collection.

Analysis and modelling

To compute and visualize the plant pollinator network data were processed in Python with the libraries Numpy and Pandas and plotted Sankey Diagrams with the library plotly.

To elaborate a model that predicts the most suitable areas for bees in the city of Milan the bayesian data driven model weight of evidence with a spatial component using the SDM toolbox for ArcMap was used (Bonham-Carter et al., 1990). Ecological and enviromental data in the municipality of Milan were used as evidential layers (Comune di Milano, 2021). For training points only non-*Apis* bee observations were used.

Results and discussion

Results of the observations

In all the green areas sampled, 2,372 observations have been collected in the city of Milan. Nearly all the plant monitored resulted attractive to Apoidea belonging to 51 families and 122 genera. 85 Apoidea species distributed in 21 genera and 5 families have been detected. Species identification of genera *Lasioglossum* and *Hyleus* is still ongoing. Thanks to the big dataset obtained, it was also possible to deepen the knowledge on the flight period of the species majorly represented in the city. 786 associations between bees' species and plant species have been observed. Different bee genera presented a different range of associations and preferences as shown in the comparison of two genera in Figure 1.

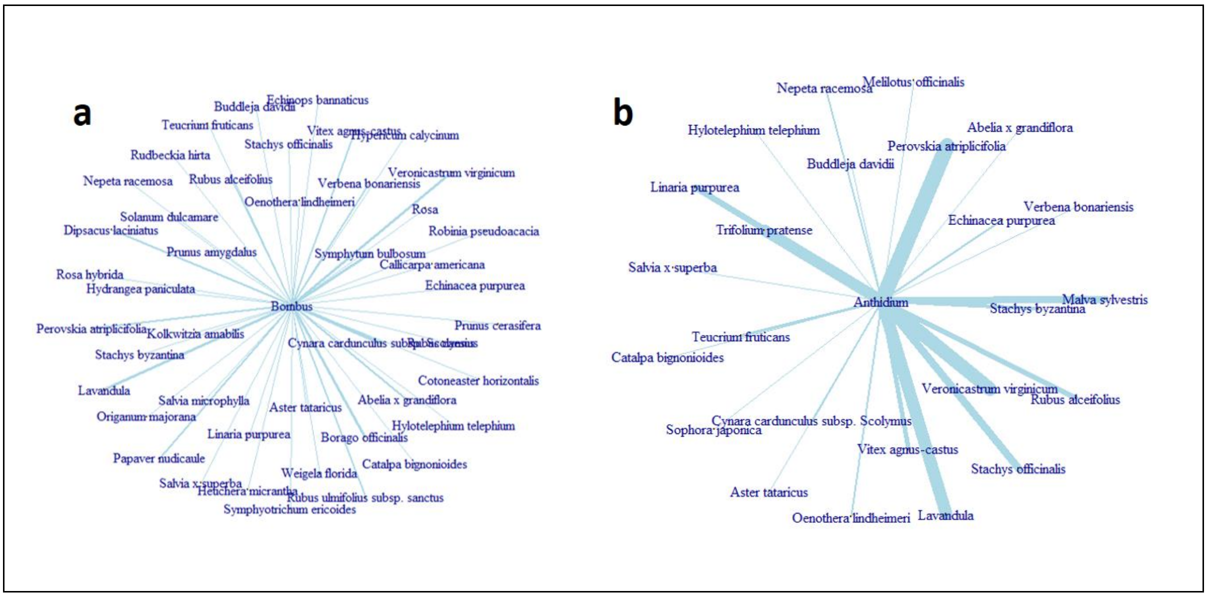


Figure 1: Examples of interaction between a bee genus and plant species: *Bombus* (a) *Anthidium* (b).

Weight of evidence model

We computed a preliminary model with observation collected during sampling in 2019-2020. As a result, we selected areas with a higher probability to host bees useful to validate the model in 2021. In most of these areas, this information was confirmed also in 2021 sampling.

Conclusions

The data acquired allow to update information on bee presence and biodiversity in a big metropolis in northern Italy. The numerous bee/plant interaction founded allow to evidence that urban environment, if appropriately designed, can sustain bee biodiversity. Despite being preliminary the weights of evidence model seem a promising predictory tool to locate suitable areas for bees.

Acknowledgements

The project was funded by Cariplo foundation Project Api-GIS grant number 2019-4675. Authors thank Michele Zilioli and Fabrizio Rigato of Museo Civico di Storia Naturale of Milano and the Department of Green of Comune of Milano.

References

Amiet, F., Herrmann, M., Müller, A., and Neumeyer, R. 2001: Fauna Helvetica APIDAE 3: *Halictus*, *Lasioglossum*; Centre suisse de cartographie de la faune (CSCF Info Fauna) Schweizerische Entomologische Gesellschaft (SEG/SES): Bern, Switzerland. ISBN: 9782884140171.

Amiet, F., Herrmann, M., Müller, A., and Neumeyer, R. 2007: Fauna Helvetica APIDAE 5: *Ammobates, Ammobatoides, Anthophora, Biastes, Ceratina, Dasypoda, Epeoloides, Epeolus, Eucera, Macropis, Melecta, Melitta, Nomada, Pasites, Tetralonia, Thyreus, Xylocopa*. Centre suisse de cartographie de la faune (CSCF Info Fauna); Schweizerische Entomologische Gesellschaft (SEG/SES), Bern, Switzerland. ISBN: 9782884140324.

Banaszak-Cibicka, W., Ratyńska, H., and Dylewski, Ł. 2016: Features of urban green space favourable for large and diverse bee populations (Hymenoptera: Apoidea: Apiformes). Urban For Urban Green. 20: 448-452.

Baldock, K. C. R., Goddard, M. A., Hicks, D. M., Kunin, W. E., Mitschunas, N., Osgathorpe, L. M., Potts, S. G., Robertson, K. R., Scott, A. V., Stone, G. N., and Vaughan, I. P. 2015: Where is the UK's pollinator biodiversity? The importance of urban areas for flower-visiting insects. Proc. R. Soc. B: Biol. Sci**.** 282(1803): 20142849.

Baldock, K. C., Goddard, M. A., Hicks, D. M., Kunin, W. E., Mitschunas, N., Morse, H., Osgathorpe, L. M., Potts, S. G., Robertson, K. M., Scott, A. V., Staniczenko, P. P., Stone, G. N., Vaughan, I. P., and Memmott, J. 2019: A systems approach reveals urban pollinator hotspots and conservation opportunities. Nat. Ecol. Evol. 3(3): 363-373.

Bonham-Carter, G. F., Agterberg, F. P. and Wright, D. F. 1990: "Weights of evidence modelling: a new approach to mapping mineral potential". In: Stat. Appl. Earth Sc. (eds. Agterberg, F. P. and Bonham-Carter, G. F.): 171-183. Geological Survey of Canada, Paper 89-9.

Comune di Milano 2021. Geoportale del Comune di Milano. Patrimonio del Verde. URL https://geoportale.comune.milano.it/sit/patrimonio-del-verde/. Accessed 17 Dec. 2021.

Falk, S. 2019: Field Guide to the bees of Great Britain and Ireland. Bloomsbury Publishing, London. ISBN: 9781472970374.

Fischer, L. K., Eichfeld, J., Kowarik, I., and Buchholz, S. 2016: Disentangling urban habitat and matrix effects on wild bee species. PeerJ. 4: e2729.

Iwasaki, J. 2017: Interactions between bee species in relation to floral resources Thesis, Doctoral of Philosophy. University of Otago.

Jones, E. L., and Leather, S. R. 2012: Invertebrates in urban areas: a review. EJE. 109(4): 463-478.

Lassini, P., Sala, G. and Bertin, L. 2014: Spazi verdi: manuale di progettazione e gestione agro-ambientale, Edagricole, Milano, Italia: 51-57.

Nieto, A., Roberts, S. P. M., Kemp, J., Rasmont, P., Kuhlmann, M., García Criado, M., Biesmeijer, J. C., Bogusch, P., Dathe, H. H., De la Rúa, P., De Meulemeester, T., Dehon, M., Dewulf, A., Ortiz-Sánchez, F. J., Lhomme, P., Pauly, A., Potts, S. G., Praz, C., Quaranta, M., Radchenko, V. G., Scheuchl, E., Smit, J., Straka, J., Terzo, M., Tomozii, B., Window, J. and Michez, D. 2014: European Red List of bees. Luxembourg: Publication Office of the European Union.

Quaranta, M., Cornalba, M., Biella, P., Comba, M., Battistoni, A., Rondinini, C., and Teofili, C. (eds.) 2018: Lista Rossa IUCN delle api italiane minacciate. Comitato Italiano IUCN e Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Roma.

Sánchez-Bayo, F., and Wyckhuys, K. A. 2019: Worldwide decline of the entomofauna: A review of its drivers. Biol. Conservation 232: 8-27.

Theodorou, P., Radzevičiūtė, R., Lentendu, G., Kahnt, B., Husemann, M., Bleidorn, C., Settele, C., Schweiger, O., Grosse, I., Wubet, T., Murray, T. E., and Paxton, R. J. 2020: Urban areas as hotspots for bees and pollination but not a panacea for all insects. Nat. Comm. 11(1): 1-13.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 30-34

Biodiversity monitoring and management in a hilly olive grove agroecosystem – the Italian case study from the FRAMEwork project

Simone Marini[1], Malayka Samantha Picchi[1], Virginia Bagnoni[1], Tiziana Sabbatini[1], Ruggero Petacchi[1], Anna-Camilla Moonen[1]
[1]*Institute of Life Sciences, Scuola Superiore Sant'Anna, Via Santa Cecilia 3, 56127 Pisa, Italy*
E-Mail: s.marini@santannapisa.it, m.picchi@santannapisa.it, c.moonen@santannapisa.it

Abstract: To implement successful biodiversity conservation strategies, management should take place at landscape scale since most organisms have a high mobility. Local farmers and citizens of the local area should be involved. In the municipality of Calci, (Pisa, Italy) we involved 16 olive growers and we organized them in a farmer cluster to define biodiversity objectives and to reach a coherent landscape management plan. In 2021, we carried out baseline biodiversity sampling in six km^2, and in six more km^2 as control sites in the nearby municipality of Vicopisano and we sampled butterflies using transect walks. We found the sampling effort sufficient and butterflies were more abundant and rich in June. Only a few butterfly species determined a variation among habitats, but the data scarcity hampered to draw conclusion about their conservation value, neither their role in the habitats. By contrast, mean butterfly vagility, i.e. the ability to move in the environment, did change through the season and habitats, thus in future we may concentrate our efforts in specific habitats and sampling time to better understand the role of these in supporting the butterfly communities.

Key words: Farmer cluster, butterflies, H2020 project, Monte Pisano

Introduction

A successful biodiversity friendly agriculture needs to be supported by the local farming community. Therefore, participatory research based on bottom-up approaches and encouraging information exchange among players is increasingly recognised as relevant by official institutions and researchers. This is the goal of the H2020 project, FRAMEwork (https://www.framework-biodiversity.eu/) which aims to build up farmer clusters to define locally relevant biodiversity objectives and to set up a landscape scale agroecosystem management plans (Niamh McHugh et al., 2022. In this paper, we present the first year's experience of sampling farmland biodiversity in the Italian olive grove cluster. In this first year, we measured the baseline biodiversity level in a before-after-control-impact (BACI) experiment design, because no common landscape management actions have yet been implemented. This sampling will be repeated after four years to monitor the changes in biodiversity. The baseline data allow us to test the following hypotheses: (i) the sampling methodology is sufficiently accurate to detect a sufficient number of species; (ii) different habitats support different butterfly communities as can be seen from the species abundance and richness patterns; (iii) each habitat will support a number of unique species which need specific conservation practices; (iv) species traits are linked to habitats and sampling month.

Materials and methods

The cluster area is located in Calci (Pisa – Italy), a village in the Monte Pisano area, where six Universal Transverse Mercator (UTM) grid cells of 1 km^2 were selected including at least one farmer cluster's farm. The control area, consisting of another six UTM grid cells, was laid out in the nearby area of Vicopisano where no farming cluster was set up. In each UTM square, we defined a sampling transect of 1 km length, including as many cluster farms as possible, and we surveyed diurnal butterflies (Lepidoptera: Rhopalocera). Four different key habitat types were defined and investigated: (i) olive groves (OL); (ii) herbaceous linear elements (HL) such as farmland paths, dry-stone walls or road verges; (iii) woody linear elements (WL) such as hedgerows either planted or managed natural ones; (iv) and finally woody areal elements (WA) which were woodlands of mixed woody vegetation. Along the transect, 16 sub-transects of 50 m length were established, each one belonging to one of the habitats described above. We walked once in each subsection three times (3-16 June 2021, 8-15 July 2021 and 20-23 September 2021) after dawn and before dusk (the earliest was 7:30, the latest was 18:30, and the median was 11:42). During each walk, an operator walked a steady and constant pace of 10 m/minute counting all the individual butterflies in an area of 2.5 m either side, 5 m ahead and 5 m above the ground. All the individuals were assigned to a species or a morpho-group if their identification in the field was not possible. Morpho-group samples were identified in the laboratory. Transects were walked during optimal weather for wild bee and butterfly sampling (Pollard and Yates, 1993). The species trait we selected for butterflies is 'vagility', which represents the ability of the species to move in the environment. Vagility was ranked into five classes (from 1 representing the lowest, to 5 representing the highest vagility) depending on the potential mobility of the species: from highly mobile to sedentary. Since the definition of vagility includes the aptitude of a species to move in different environments, it could be linked to the resources in the area and to management impacts (Ferrando et al., 2012).

To test hypothesis (i), we built rarefaction-extrapolation curves using the R package iNext (v. 2.0.20, Hsieh et al., 2016) and treated all the subsections as sampling units. Species presence in each sub-section was used to build the rarefaction curves. To test hypothesis (ii), a generalized linear mixed model (GLMM) with negative binomial error distribution was built; square ID was included as a random factor. To test hypothesis (iii), we performed a redundancy analysis (RDA) or canonical-correlation analysis (CCA) using butterfly species abundances as a species matrix and sampling month and habitat type as environmental factors. For the analysis we used the R package vegan (v. 2.5.7, Oksanen et al., 2016) To test hypothesis (iv), a linear mixed model (LMM) was built; square ID was included as a random factor. The distribution in time and the interaction with habitat types were also included. The analysis has been restricted to the species with a classified vagility score. For GLMM and LMM analyses we used the R package lme4 (v. 1.1.26, Bates et al., 2015). Models post hoc tests were performed using the package emmeans (v. 1.7.2, Russell, 2022) using chi square tests. All the analyses were performed in R version 4.0.4 (R Core Team, 2017).

Results and discussion

We found 49 butterfly species in 1317 observation events. Rarefaction-extrapolation curves demonstrated that in each habitat sufficient sampling effort had been undertaken (Figure 1). The sample completeness was 79.6 % in olive groves, 84.7% in herbaceous linear elements, 76.4 % in woody areal sites and 82.7 % in woody linear elements. In subsequent years, sampling will start earlier, adding one sampling in April or May, to enable more species to be collected.

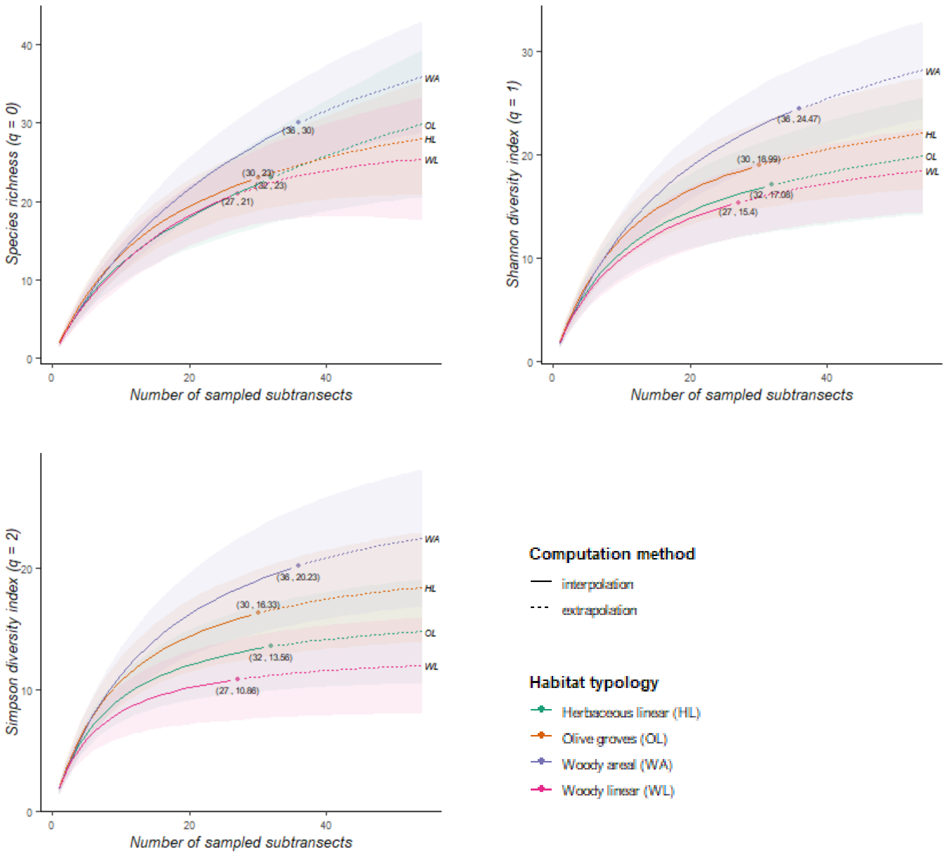


Figure 1. Rarefaction and extrapolation curves computed as incidence data across the subtransects and sampling times throughout the season in the farmer cluster farms and the control farms, located respectively in Calci and Vicopisano – Monte Pisano area, Pisa, Italy.

Butterfly species abundance per subsection was higher in June, lower in July, and intermediate in September [$\chi^2 = 28.657$, $p < 0.0001$], a result in line with expectation. Habitat type did not explain butterfly abundance. Butterfly richness was again higher in June compared to July, with September in the middle of the two [$\chi^2 = 11.9287$, $p < 0.0026$]. The results do not confirm hypothesis (ii), encouraging a rethink of the defined classifications. Alternatively other characteristics of the environment which may have driven butterfly abundance and richness, such as the vegetation composition, should be taken into account. This will be sampled in 2022.

Hypothesis (iii) was not supported by the butterfly community variation with respect to habitat type and sampling month. The variation explained by the constrained axes was too low (RDA percentage of explained variation was 7.26 %). The analysis was repeated with only the species which had at least 5 observations, but the result did not change (RDA percentage of explained variation 5.32 %). Only a few species emerged from the first analysis, but due to their scarcity we cannot draw conclusion about their conservation value, neither their role in the habitats. In subsequent years, we hope to collect more data to disentangle the question.

Hypothesis (iv) was supported by the data (Figure 2), since habitat type [$\chi^2 = 9.0868$, $p = 0.028$], month [$\chi^2 = 18.634$, $p = < 0.0001$], and their interaction [$\chi^2 = 14.027$, $p = 0.029$] explained the variation in butterfly vagility. In particular, the role of olive groves and woody areal elements seems to change in the season, hosting butterflies which were more mobile in July. We cannot draw a conclusion of this shift with the data we have got at this time. However, since July is characterized by drought and a lack of resources, we may concentrate our efforts on this month to better understand the role of these habitats in supporting butterfly communities. Finally, we may propose a management strategy to farmers in order to increase resources for butterflies in summer.

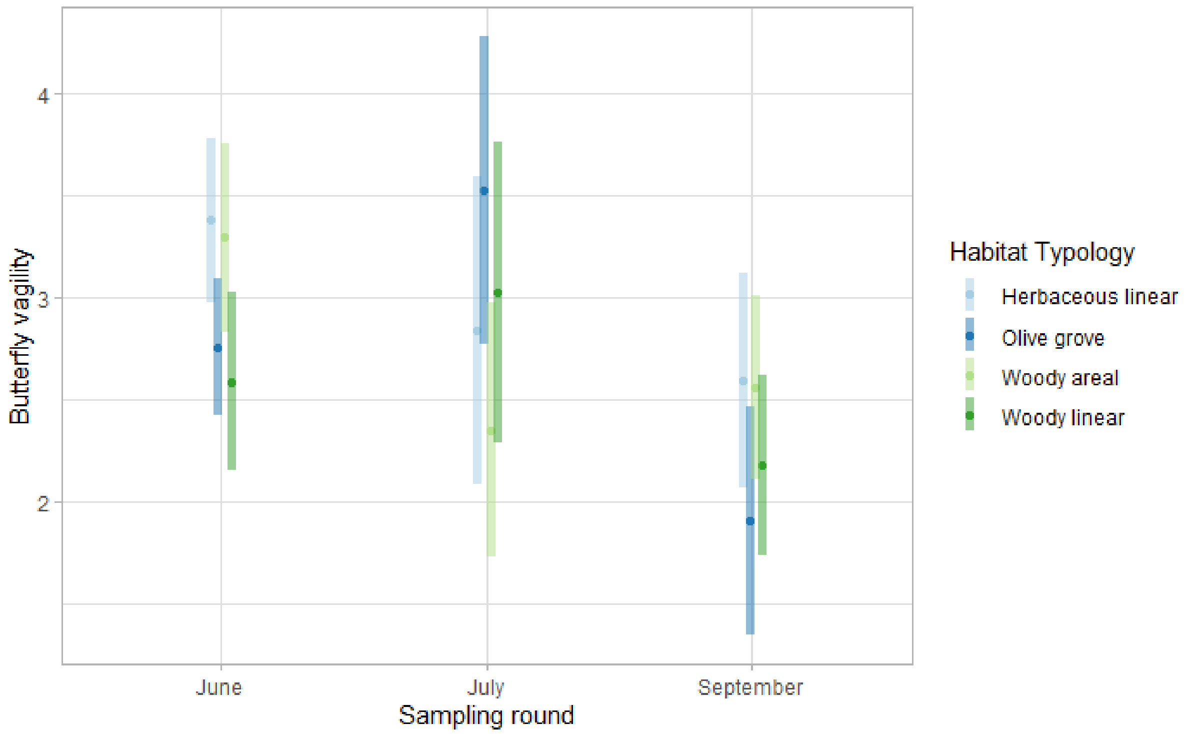


Figure 2. Butterfly vagility in relation to sampling month and habitat type for the butterflies collected in Calci and Vicopisano in 2021. Results come from the Linear Mixed Model. Dots represent the estimated marginal mean computed *and b*ars among points report the 95 % confidence interval.

Acknowledgements

We thank Sportello di Agroecologia di Calci for the big effort they are taking to help the project. Without their help, this project would have had many more problems to find the farmers. Thanks also to the colleagues and students who helped to sample biodiversity: Stefano Carlesi, Federico Leoni, Pauline Triboulet and Marta Valicenti.

References

Bates, D., Mächler, M., Bolker, B. M., and Walker, S. C. 2015: Fitting linear mixed-effects models using lme4. J. Stat. Softw.: 1-51. https://doi.org/10.1177/009286150103500418

Hsieh, T. C., Ma, K. H., and Chao, A. 2016: iNEXT: an R package for rarefaction and extrapolation of species diversity (Hill numbers). Methods Ecol. Evol. *7*(12): 1451-1456.

McHugh, N. et al. 2022: Farmer Clusters: A FRAMEwork for connecting conservation measures in agricultural landscapes. IOBC-WPRS Bulletin 156: 66-70.

Ferrando, S., Quirino, M., Alliani, N. 2012: Relazione finale di secondo anno/Monitoraggio lepidotteri. In: Programma di Sviluppo Rurale 2007-2013: monitoraggio degli indicatori agricoli, forestali e ambientali finalizzato alla valutazione in itinere, assistenza tecnica all'autorità di gestione. Regione Piemonte.

Oksanen, J., Blanchet, F. G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P. R., O'Hara, R. B., Simpson, G. L., Solymos, P., Stevens, M. H. H., Szoecs, E., and Wagner, H. 2016: vegan: Community Ecology Package. https://cran.r-project.org/package=vegan

Pollard, E., and Yates, T. J. 1993: Monitoring butterflies for ecology and conservation: the British butterfly monitoring scheme. Springer Science & Business Media.

R Core Team. 2017: R: A Language and Environment for Statistical Computing. https://www.r-project.org/

Russell, L. 2018: Emmeans: estimated marginal means, aka least-squares means. R package version 1(2).

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 35-39

FlowerFinder: An open source tool for automated flower detection and counting in UAV images and orthomosaics

Maximilian Sittinger[1], Justus Scheil[2], Annette Herz[1], Burkhard Golla[2]
[1]Julius Kühn Institute, Institute for Biological Control, Schwabenheimer Straße 101, 69221 Dossenheim, Germany; [2]Julius Kühn Institute, Institute for Strategies and Technology Assessment, Stahnsdorfer Damm 81, 14532 Kleinmachnow, Germany
E-Mail: annette.herz@julius-kuehn.de; burkhard.golla@julius-kuehn.de

Abstract: In the face of current reports of declines in insect abundance and diversity, measures such as agri-environment schemes for habitat conservation are necessary to prevent a severe loss of important ecosystem services. One of the possible options for farmers to increase the habitat quality for flower-visiting insects is to reduce the management intensity of grassland sites. To prove the efficacy of this measure, the number of specific indicator plant species is usually assessed. We are developing a processing pipeline for UAV (unmanned aerial vehicle) imagery that could enhance this assessment by automated detection and counting of individual flowers for plots, transects or entire meadows.

Key words: biodiversity, conservation, deep learning, flowers, grassland, pollinators, UAV

Introduction

Insect populations are declining worldwide, with two of the major drivers being agricultural intensification and habitat loss (Sánchez-Bayo and Wyckhuys, 2021). Long-term studies from Germany not only provide evidence for a substantial decline in insect biomass, abundance and diversity (Hallmann et al., 2017; Seibold et al., 2019), but also for declines in the occurrence of more than 70 % of plant species (Eichenberg et al., 2021). A loss of flowering plant diversity and occurrence can directly impact population sizes of pollinators and other beneficial insects, which depend on nectar and pollen as food resources (Potts et al., 2010).

To preserve biodiversity and provision of ecosystem services like pollination and natural pest control, an easily implementable option for farmers of agricultural grasslands is to enhance the habitat quality for insects by reducing management intensity and thereby promoting flowering plant species richness and floral resource availability for insects (Potts et al., 2009).

The requirements to enter results-based agri-environment schemes for species-rich grassland in the EU are mainly based on the number of specific indicator plant species present along a transect (European Commission, 2014). This estimation of habitat quality excludes sites that are flower rich but still do not meet the required threshold of indicator plant species.

Current methods in the fields of remote sensing and deep learning allow a more precise assessment of flower abundance. As shown in previous studies (Gallmann et al., 2020), the detection of individual flowers in UAV images could significantly decrease the required time for plant surveys, while increasing the accuracy and spatial extent of these assessments. We are developing an open source processing pipeline, that detects and counts flowers in single UAV images (e. g. of plots in an experimental study) or orthomosaics, covering entire grassland sites. The generated output can be directly loaded into standard GIS software and includes information of the total detected number of flowers and the respective size and detection confidence score for each individual flower.

Materials and methods

UAV image acquisition and processing

We took images of 16 meadows with a commercial UAV (DJI Mavic 2 Pro) at several dates during 2020. Images were taken from the entire sites at an altitude of 50 m and of ~25 m wide transects at an altitude of 15 m. All images had an overlap of 70 % to allow further processing to orthomosaics with the photogrammetry software Pix4Dfields (2021).

Deep learning model training

We used images from a site with high flower abundance for labeling and training the object detection model. Labeling was done in the online platform Roboflow (https://roboflow.com, 2021). Thirrteen original images were split into 6 x 4 tiles with an resolution of 912 × 912 px, resulting in a total of 312 image tiles used for labeling the flowers. In 272 of these images, 13,296 annotations were made across two classes (white flowers: 10,875; yellow flowers: 2,421). Since the class imbalance caused a decrease in accuracy, we merged both classes into one class for model training. The model was trained on a RTX3070 Nvidia GPU. For users wishing to retrain the model with their own data, a free cloud GPU from Google Colab could be used. The open source object detection architecture YOLOv5s (Jocher et al., 2022) achieved high detection accuracy and good performance.

Pipeline development for variable image/orthomosaic input size

Most object detection frameworks like YOLOv5 can not deal with high resolution images without splitting the images into smaller tiles beforehand. However, simple tiling of the original images would result in low quality detections because many objects would be cut in half. To avoid this problem, we are using the YOLTv5 framework, which enables the input of images of arbitrary size (https://github.com/avanetten/yoltv5, 2022; van Etten, 2019). Partitioning of the images is achieved via a sliding window approach with a specified overlap between tiles and overlapping detections are removed by applying non-maximal suppression to the bounding box predictions to keep only those detections with the highest confidence score in the final GeoJSON output.

Results and discussion

Model accuracy and performance

The current model achieves a recall of 0.83 (83 % of the flowers are found) and a precision of 0.86 (86 % of the found flowers are correct detections). The mean average precision (mAP) of the model for an intersection over union (IoU) threshold of 0.5 is 0.93. With a Nvidia RTX3070 GPU inference time for a 0.87 ha orthomosaic [transect shown in Figure 1 (a)] is 5 min (1750 m^2 / min). Inference time on an Intel i7 6700k CPU for the same orthomosaic is 16 min.

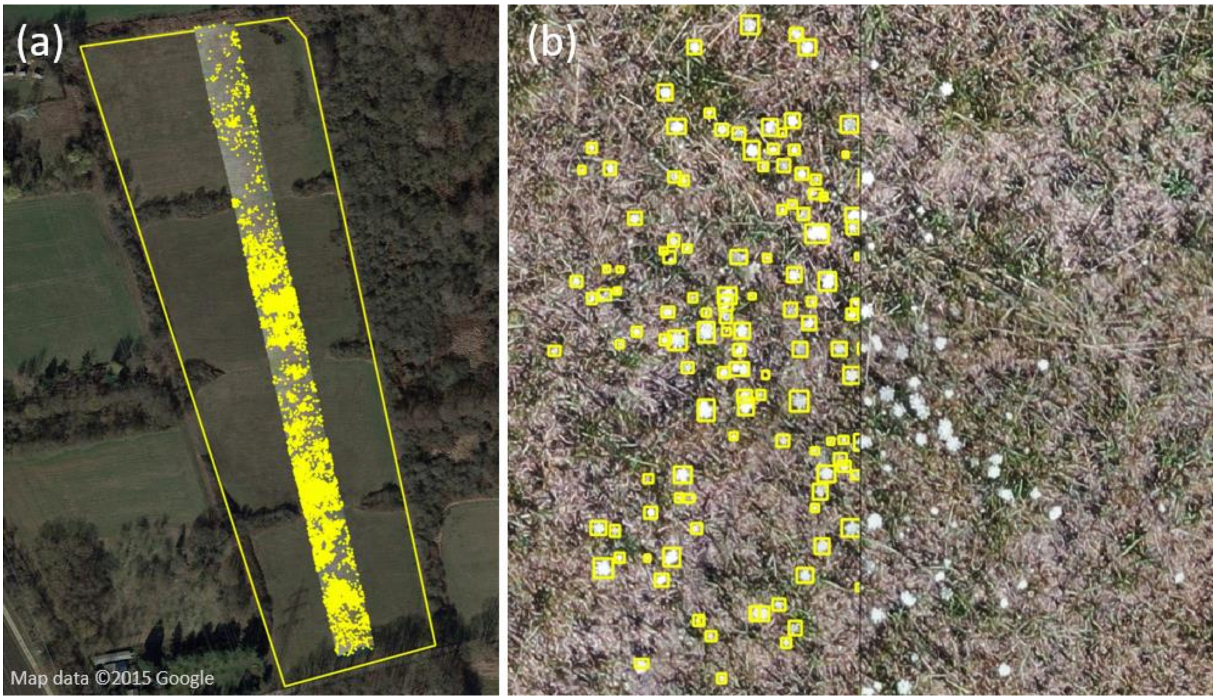


Figure 1. (a) Detected flowers in an orthomosaic from a transect with an extent of 380 × 23 m, located in the center of a 4.3 ha meadow. (b) Split screen showing a part of the original UAV image on the right side and after inference with the flower detection model on the left side.

Model inference

To test inference with the flower detection model, we used the orthomosaic, which input images also contained the 13 training data set images. In Figure 1 (a) the orthomosaic (380 × 23 m transect across the meadow) is shown with a total of 25,140 detected flowers. Figure 1 (b) shows a section of the orthomosaic before inference on the right and after inference with the detected flowers on the left side. Of all detected flowers, 17,671 (70 %) had a detection confidence score of > 0.3, which can be visualised by categorizing the detections [bounding boxes/polygons) in QGIS (2022) (Figure 2 (c)].

Possible applications

Agri-environment schemes for species-rich grassland in the EU are mainly designed for high plant diversity or (rare) indicator species. Incorporating floral resource availability for insects would increase the scope of possible funding for farmers. Especially Apiaceae (e. g. *Daucus carota* L.; *Anthriscus sylvestris* L.) are often not included in the lists of indicator species, despite their high value as food resource for many insects (Balfour and Ratnieks, 2022). Even without a more specific classification of the flowering plant species, the flower size [Figure 2 (a) and (b)] and amount of floral area per site could be used to estimate the potential support for pollinators and natural enemies (Lundin et al., 2019). The confidence score for each detected flower can be used to adjust the accuracy of the estimated floral abundance, depending on the use case.

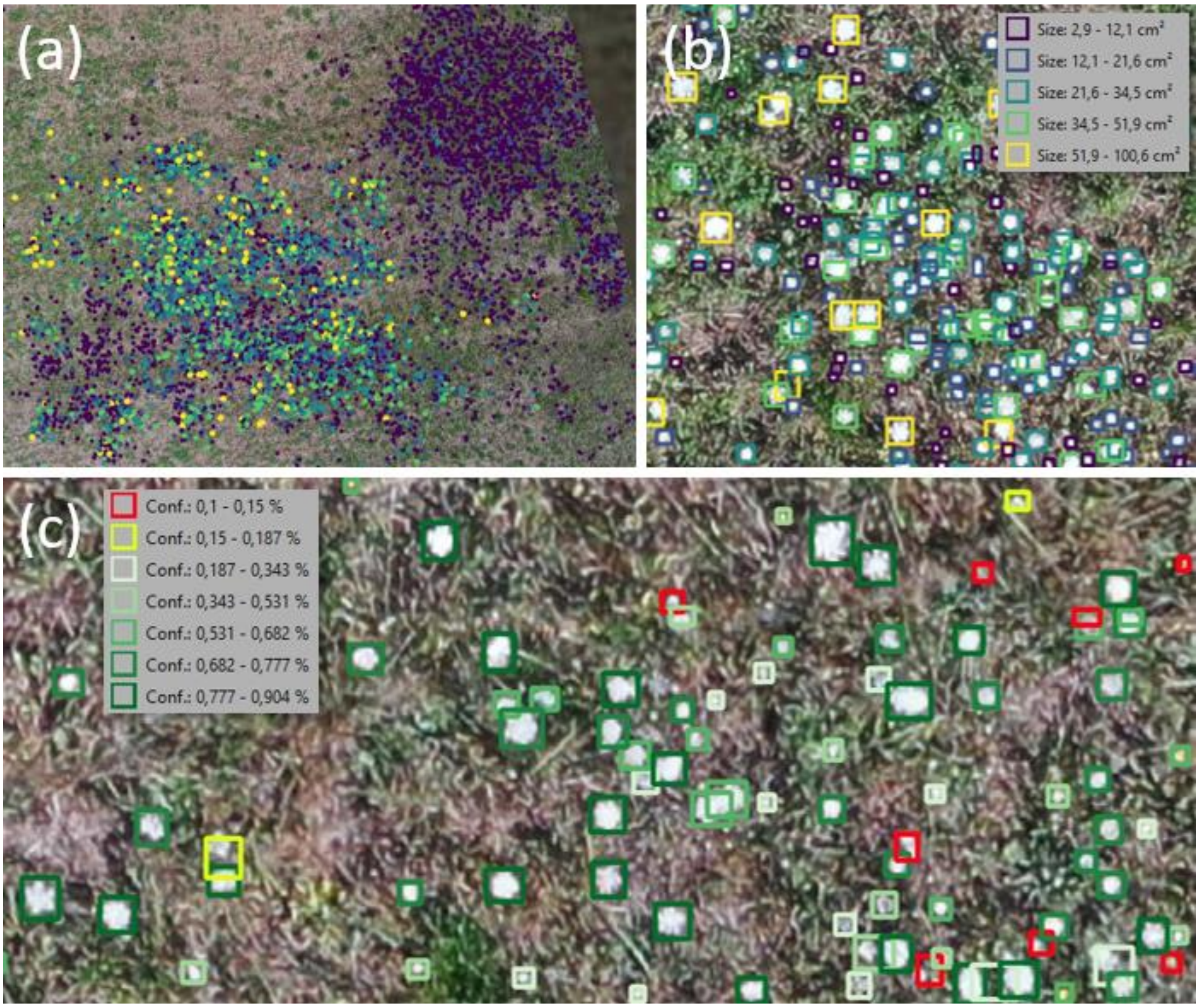


Figure 2. (a) (b) Detected flowers labelled by five different size categories (size of the bounding box/polygon in QGIS). In (a) differences in flowering plant species per flower patch can be recognized. (c) Detected flowers categorized and labelled by detection confidence score.

References

Balfour, N. J. and Ratnieks, F. L. W. 2022: The disproportionate value of 'weeds' to pollinators and biodiversity. J. Appl. Ecol. 59(5): 1209-1218.

Eichenberg, D., Bowler, D. E., Bonn, A., Bruelheide, H., Grescho, V., Harter, D., Jandt, U., May, R., Winter, M., and Jansen, F. 2021: Widespread decline in Central European plant diversity across six decades. Glob. Change Biol. 27(5): 1097-1110.

European Commission, Directorate-General for Environment 2014: Maintenance of species rich grassland through results-based agri-environment schemes – Germany, various Länder. URL https://ec.europa.eu/environment/nature/rbaps/fiche/maintenance-species-rich-grassland-through-results_en.htm. Accessed 22 Apr. 2022.

Gallmann, J., Schüpbach, B., Jacot, K., Albrecht, M., Winizki, J., and Aasen, H. 2020: Flower Mapping in Grasslands with Drones and Deep Learning. Authorea. doi:10.22541/au.158740047.73964506

Hallmann, C. A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., Stenmans, W., Müller, A., Sumser, H., Hörren, T., Goulson, D., and de Kroon, H. 2017: More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PLoS ONE. 12(10): e0185809. doi:10.1371/journal.pone.0185809

Jocher, G., Ayush Chaurasia, A., Stoken, A., … Thanh Minh, M. 2022: ultralytics/yolov5: v6.1 - TensorRT, TensorFlow Edge TPU and OpenVINO Export and Inference (v6.1). Zenodo. doi:10.5281/zenodo.6222936

Lundin, O., Ward, K. L., and Williams, N. M. 2019: Identifying native plants for coordinated habitat management of arthropod pollinators, herbivores and natural enemies. J. Appl. Ecol. 56(3): 665-676.

Pix4Dfields, version 1.10.1. 2021: Pix4D SA. http://www.pix4d.com

Potts, S. G., Woodcock, B. A., Roberts, S. P. M., Tscheulin, T., Pilgrim, E. S., Brown, V. K., and Tallowin, J. R. 2009: Enhancing pollinator biodiversity in intensive grasslands. J. Appl. Ecol. 46(2): 369-379.

Potts, S. G., Biesmeijer, J. C., Kremen, C., Neumann, P., Schweiger, O., and Kunin, W. E. 2010: Global pollinator declines: Trends, impacts and drivers. Trends Ecol. Evol. 25(6): 345-353.

QGIS, version 3.24.2. 2022: QGIS Geographic Information System. QGIS Association. http://www.qgis.org

Sánchez-Bayo, F., and Wyckhuys, K. A. G. 2021: Further evidence for a global decline of the entomofauna. Austral. Entomol. 60(1): 9-26.

Seibold, S., Gossner, M. M., Simons, N. K., Blüthgen, N., Müller, J., Ambarlı, D., Ammer, … Weisser, W. W. 2019: Arthropod decline in grasslands and forests is associated with landscape-level drivers. Nature 574(7780): 671-674.

van Etten, A. 2019: Satellite Imagery Multiscale Rapid Detection with Windowed Networks. 2019 IEEE (WACV): 735-743.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 40-44

The contribution of Mediterranean native shrub species to greenspaces

Daniela Romano[1], Stefania Toscano[1], Ilda Vagge[2], Antonio Ferrante[2]
[1]University of Catania, Department of Agriculture, Food and Environment, Via Valdisavoia 5, 95123 Catania, Italy; [2]University of Milan, Department of Agricultural and Environmental Sciences, Via Celoria 2, 20133, Milano, Italy
E-Mail: antonio.ferrante@unimi.it

Abstract: To obtain sustainable ornamental greenspaces, the choice of the species is increasingly addressing to native plants. This choice can represent a valid solution, thanks to remarkable adaptability of native plants to biotic and abiotic stresses. The Mediterranean basin is one of the major world centres for plant diversity, with around 25,000 species. Shrubs are a very common type of plant in the Mediterranean and constitute the typical vegetation of this ecosystem, the so-called in Italian "macchia". Moreover, thanks to their anatomical, morphological, physiological, and biochemical characteristics, these plants are able to tolerate abiotic stress and in particular drought. In this context, we analysed the contribution of native shrubs to realization of greenspaces. The results acquired showed the high number of Mediterranean chorotype shrub species potentially used for ornamental purposes. A total of 148 species were surveyed belonging to 40 botanical families. Relevant is the incidence of Asteraceae with 25 species (16.9 % of the total), followed by Fabaceae (17 species, 11.5 %), Lamiaceae (15 species, 10.1 %), Rosaceae (14 species, 9.5%) and Cistaceae (10 species, 6.8 %). Specific sheets with useful information were collected for 118 species, belonging to 38 botanical families, including the possible use of the species for ornamental purposes, were realized.

Key words: biodiversity, plant species choice, ornamental plants, Mediterranean chorotypes.

Introduction

The use of plants resilient to environmental stress is a good solution to increase the sustainability of urban greenspaces (parks, gardens, urban forests, etc.). For this reason the role of native plants becomes more relevant (Iles, 2003). Traditionally these plants have been ignored in the ornamental landscapes, in the last years, but currently interest in them has been growing in the sustainable landscape (Jimenez et al., 2022). Many of the native species represent an alternative to the traditional ornamental plant species, especially in semi-arid ecosystems, such as the Mediterranean one. These plant species show a resistance to diseases and high salt level, high efficiency in water consumption, specific growth modalities (Clary et al., 2004). Native plants are characterized by the numerous morphological and physiological strategies that allow them to overcome abiotic stresses; the adaptability of these plants, however, strongly changes between the different species and within the species itself (Ferrante et al., 2021).

The use of native plants in the Mediterranean Basin is supported by the wide biodiversity that characterizes this environment, considered a great reserve of plant biodiversity. Around 25,000 plant species are present in this environment. Furthermore, the Mediterranean flora includes a high percentage of endemic species (Mèdail and Quèzel, 1999). In this frame, the potential of the Sicilian flora, also due to the great exclusive biodiversity that characterizes the island, is high and certainly not adequately exploited so far. Sicily (25,700 km^2, equal to 8.5 % of the Italian territory), in fact, thanks to its position, is the center of origin of many species; the presence of 3,200 species has been estimated (Raimondo et al., 2010), which represent almost 50 % of the entire consistency of the flora of Italy. Characteristic elements of the flora of Sicily are the high concentration (over 23 %) of stenomediterranean species, the presence of numerous endemic species which account for 7.6 % of the total (Raimondo et al., 2010). Among the native plant species, the shrubs, which are the protagonists of the typical Mediterranean vegetation, the "macchia" in Italian, represent a type of plant which, due to its small stature, resilience, ornamental features, lends itself very well to the needs of creating "sustainable" green spaces (Romano and Scariot, 2021). In this context, the objective of the work was to carry out a review of the shrub species present in Sicily of Mediterranean chorotypes, in view of their possible ornamental use in drought environments.

Materials and methods

The survey was started with the consultation of some bibliographic sources (Pignatti, 1982; Raimondo et al., 2010) which allowed to define the first group of species; all the plants identified belonged to the group of so-called bushes (chamaephytes and nanophanerophytes according to Raunkiaer). The list obtained (data not shown) was limited to the species present in Sicily, of Mediterranean chorotypes, which were not significantly present in the current nursery offer.

For the species of greatest interest, a descriptive card has been prepared (Figure 1), which contains some useful information for subsequent studies (family, Raunkiaer plant life-form, chorotype, International Union for Conservation of Nature category, distribution, blooming period, morphological description, features of ornamental interest. Furthermore, for each species, using google scholar (https://scholar.google.it/), the available references were investigated, reporting the most significant ones for the purposes of the survey.

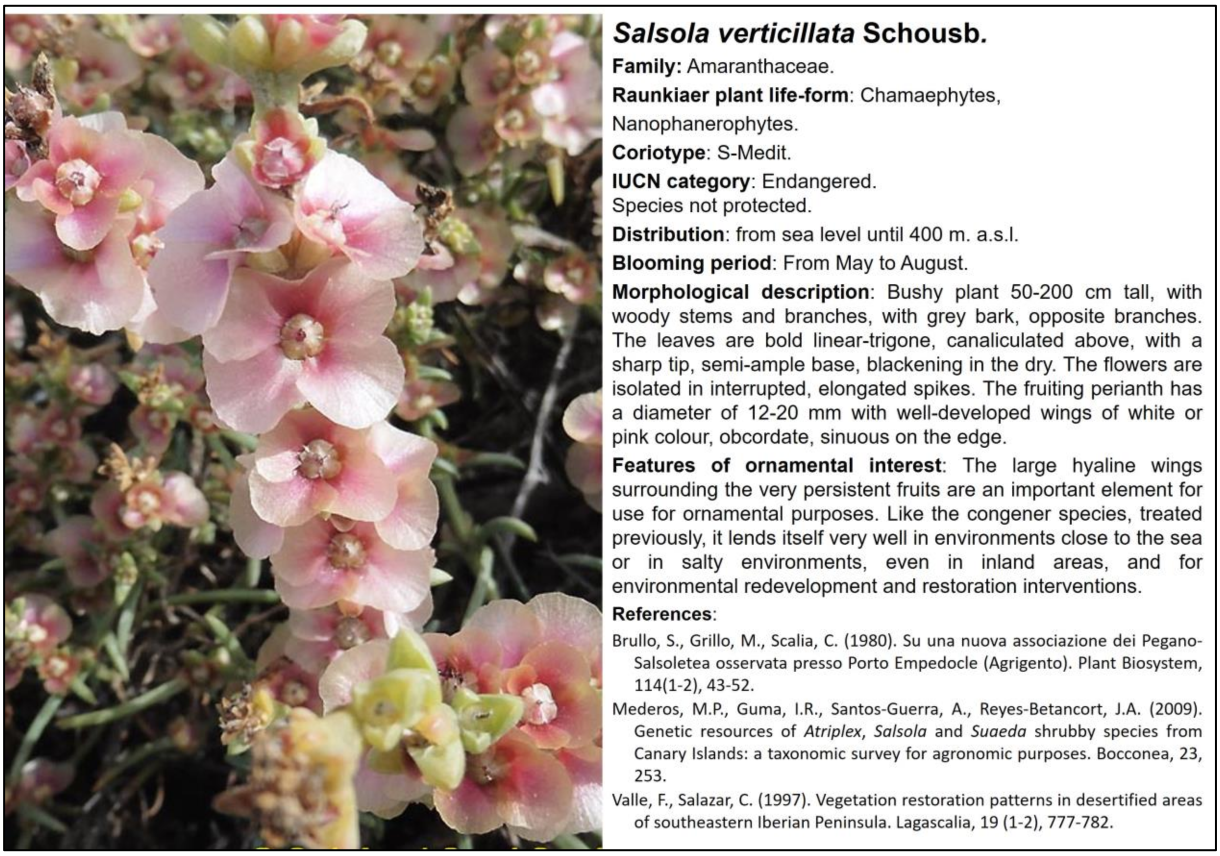


Figure 1. Structure of the descriptive card.

Results and discussion

The survey allowed to identify 148 species belonging to 40 different botanical families. Relevant is the incidence of Asteraceae with 25 species (16.9 % of the total), followed by Fabaceae (17 species, 11.5 %), Lamiaceae (15 species, 10.1 %), Rosaceae (14 species, 9.5 %), and Cistaceae (10 species, 6.8 %) (Figure 2 A).

Their adaptability, even if further research is needed to verify agronomic adaptability, is confirmed by several parameters: morphological characteristics of the whole plant, rather compact habitus (pulvinate), vivacity of flower and/or fruit colors, characteristics of flowering and fruiting (times, frequencies, scaling). In particular, flowering for each species lasts an average of 3.2 ± 1.7 months and therefore appears rather concentrated; the result is connected to the characteristics of the Mediterranean environment which has a long dry summer season. In any case, the blooms are distributed throughout the months of the year, so they manage to ensure a rather persistent ornamental effect (Figure 2 B).

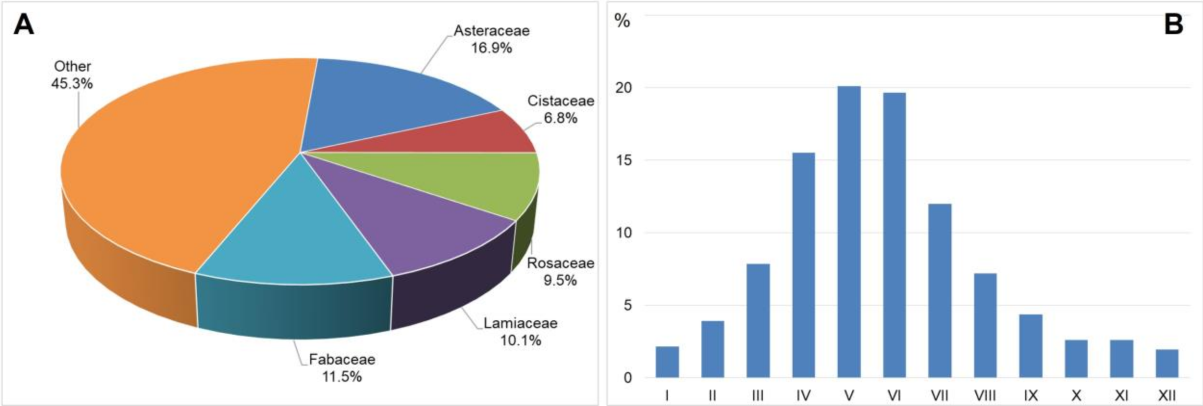


Figure 2. Main botanical families (A) and percentage distribution of flowering during the different months of the year (B).

In relation to their distribution, many of these plant species are threatened species: 14.2 % of the species surveyed are very rare, 47.3 % rare (data not shown). The collection of propagation materials, to start the cultivation tests, must therefore follow the protocols for endangered plant species. 37.8% of the species surveyed are endemics and hence highly adapted to a specific geographic area and environmental conditions; it requires a detailed understanding of their ability to adapt to more man-made environments.

Figure 3. The ornamental interest of the selected species is based on showiness and bright colour of flowers, and/or plant shapes and leaf characteristics.

The overall features of these plant species allow ornamental uses (Figure 3). Plant tolerant to drought have different and interconnected morphology (Toscano et al., 2019). All the species listed are adapted to the Mediterranean bio-climate, which is characterized by at least two months of summer dryness; in particular Mediterranean shrubs with sclerophyll leaves, largely present in the list are adopted to overcome drought stress (Ferrante et al., 2021).

References

Clary, J., Savé, R., Biel, C. and de Herralde, F. 2004: Water relations in competitive interactions of Mediterranean grasses and shrubs. Ann. Appl. Biol. 144: 149-155. https://doi.org/10.1111/j.1744-7348.2004.tb00328.x.

Ferrante, A., Toscano, S., Romano, D. and Vagge, I. 2021: Physiological and morpho-anatomical traits used as markers for the selection of drought tolerance of ornamental plants. Acta Hortic. 1331: 253-260. DOI: 10.17660/ActaHortic.2021.1331.34.

Iles, J. K. 2003: The science and practice of stress reduction in managed landscapes. Acta Hort. 618: 117-124. DOI: 10.17660/ActaHortic.2003.618.11.

Jimenez, M. F., Pejchar, L., Reed, S. E. and McHale, M. R. 2022: The efficacy of urban habitat enhancement programs for conserving native plants and human-sensitive animals. Landscape and Urban Planning 220: 10435. https://doi.org/10.1016/j.landurbplan.2022.104356.

Medail, F. and Quezel, P. 1999: Biodiversity hotspots in the Mediterranean Basin: setting global conservation priorities. Conserv. Biol. 13: 1510-1513.

Pignatti, S. 1982: Flora d'Italia. Vol. I-III. Edagricole Press, Bologna, Italy.

Raimondo, F. M., Domina, G. and Spadaro, V. 2010: Checklist of the vascular flora of Sicily. Quad. Bot. Amb. Appl. 21: 189-252.

Romano, D. and Scariot, V. 2021: Woody ornamentals: a review of genetic resources in the Mediterranean area. Acta Hortic. 1331: 325-334. DOI: 10.17660/ActaHortic.2021.1331.43.

Toscano, S., Ferrante, A. and Romano, D. 2019: Response of Mediterranean ornamental plants to drought stress. Horticulturae 5(1): 6. https://doi.org/10.3390/horticulturae5010006.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 45-49

The potential of citizen science to support local biodiversity sensitive farming systems: First insights from the FRAMEwork project

Gerid Hager[1], Gitte Kragh[2], Michael K. Poulsen[2], Finn Danielsen[2], Sarah Vray[3], Youri Martin[3]
[1]International Institute for Applied Systems Analysis (IIASA), Schlossplatz 1, 2361 Laxenburg, Austria; [2]Nordisk Fond for Miljø og Udvikling (NORDECO), Skindergade 23, 3. sal, 1159 København, Denmark; [3]Luxembourg Institute of Science and Technology (LIST), 5 avenue des Hauts-Fourneaux, 4362 Esch-sur-Alzette, Luxembourg

Abstract: Unsustainable agriculture is one of the main causes for the global biodiversity crisis, happening locally, and a key frontier for halting biodiversity loss through conservation and promotion of biodiversity sensitive management. The EU H2020 "FRAMEwork" project encourages local farmer and stakeholder groups with a shared interest in improving biodiversity-friendly farming on a landscape scale as well as participation in biodiversity monitoring on their farms together with scientists and local communities. The integration of different citizen science concepts and formats with the farmer cluster approach can maximise their individual strengths and support evidence-based, locally embedded and scalable collaboration towards biodiversity protection and enhancement.

Key words: citizen science, biodiversity monitoring, farmland, communities

Introduction

Unsustainable agricultural activity is one of the main causes for the global biodiversity crisis, happening locally, and agriculture is a key frontier for halting biodiversity loss through conservation and increased implementation of biodiversity sensitive farm management (Dudley and Alexander, 2017). The promotion of biodiversity in agricultural landscapes can be facilitated through targeted policies, land reforms, or new agri-environmental schemes as well as by deliberately promoting farmer-led innovation and community engagement.

The EU H2020 project "FRAMEwork" supports local farmer groups with a shared interest in improving biodiversity friendly farming on a landscape scale as well as participation in biodiversity monitoring on their farms together with scientists and local communities. In eleven farmer clusters across Europe, the project aims to integrate different concepts and domains, such as *farmer clusters* and *citizen science*, into a larger whole. Farmer clusters, originating and rapidly spreading in the UK, are communities of farmers and other local actors in the same region, who work together to conserve and improve biodiversity and ecological health of farmland on a landscape scale[1]. Citizen science, succinctly derscribed as the public participation in scientific research in a non-professional capacity, has tight and long-lasting links to biodiversity monitoring and research across the globe (Pocock et al., 2018; Shirk et al., 2012). In Europe, several citizen science biodiversity monitoring initiatives focusing specifically on

[1] https://www.farmerclusters.com/

farmer engagement have developed nationally, such as the "Biodiversitätsmonitoring mit LandwirtInnen" in Austria[2], the "Observatoire Agricole de la Biodiversité" in France[3], and the "Boeren InsectenMonitoring Agrarische Gebieden" in The Netherlands[4]. While these national initiatives often foc!us on specific monitoring activities, data collection, and targeted management advice, the FRAMEwork project aims to follow a broader, systemic approach, integrating citizen science concepts and formats with the farmer cluster approach, amongst others, to maximise their individual strengths and support evidence-based, locally embedded and scalable collaboration towards biodiversity protection and enhancement.

Materials and methods

Citizen science activities in FRAMEwork focus on two main objectives: 1) engaging farmers and farming communities in collaborative biodiversity monitoring activities to improve their understanding of biodiversity for adaptive management and to complement biodiversity observations from standardised monitoring, as well as 2) providing opportunities for wider public audiences of all kinds to participate in biodiversity monitoring and awareness raising activities. Together, these activities aim at strengthening awareness about biodiversity in local communities and supporting biodiversity-friendly landscape management.

Actors and audiences

The most important actors and audiences for citizen science activities in and around farmer clusters are summarised in Figure 1. They can be target actors as well as enabling actors. Target actors are actors who the events and activities are designed and organised *for*. Enabling actors are actors who the events and activities are designed and organised *with*. Certain actors can be both, for example farmers, when they are engaged in co-defining specific goals and aspects of monitoring activites, or participating in capacity building events provided for them.

Figure 1. Actor and audience composition for citizen science activities.

[2] https://www.biodiversitaetsmonitoring.at/
[3] https://www.observatoire-agricole-biodiversite.fr/
[4] https://www.vlinderstichting.nl/bimag/

Materials and tools
The citizen science materials and tools used include validated observation protocols, data recording tools, platforms and data quality assurance mechanisms as well as well-known citizen science formats (see examples in Table 1). Such protocols, tools and formats are combined into different activity types and engagement pathways, which range from event-type activities to more long-term actions, using specified protocols.

Table 1. Examples of citizen science protocols, tools and formats in use.

Type	**Example**
Observation protocols	Earthworm sampling via a validated and simple protocol, targeted at farmers to record earthworm functional groups in agricultural land[5].
Data recording tools, platforms	iNaturalist.org: A global biodiversity observation and data recording platform and community with more than 5M members[6].
Activity format	BioBlitz: Time- and space-bound public activities to record biodiversity observations, often combined with expert talks and hands-on activities.

Results and discussion

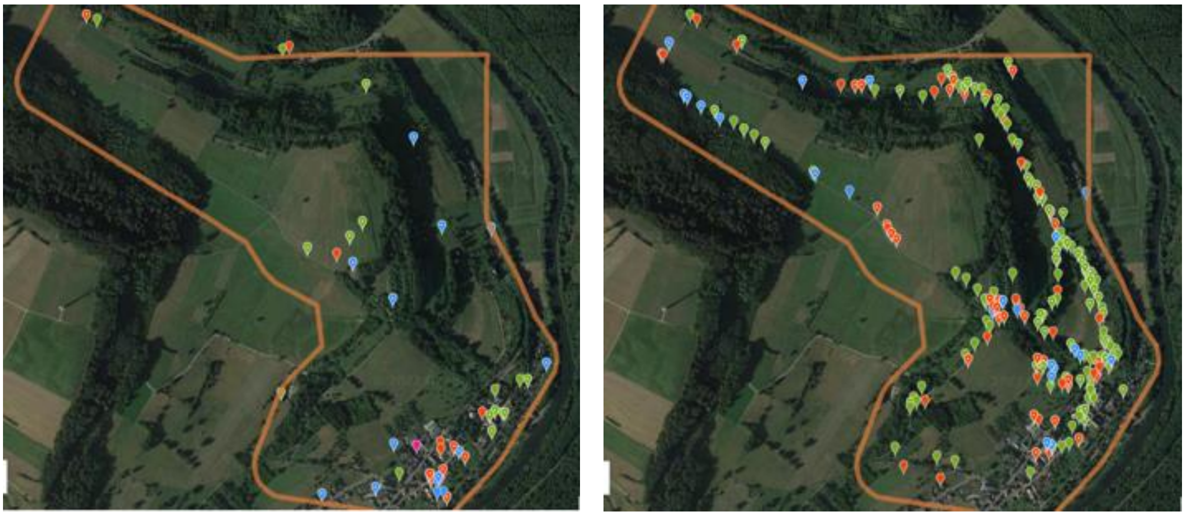
We present some first insights from a specific activity to illustrate the potential of citizen science to support local biodiversity sensitive farming systems. From April 30 to May 1, 2022, as part of the global *City Nature Challenge*, a BioBlitz was held at the Luxembourg farmer cluster, organised by FRAMEwork partners LIST, NORDECO and IIASA in collaboration with Ramborn Cider company, the local Natur- & Geopark Mëllerdall, as well as the Natural History Museum, Luxembourg. The BioBlitz consisted of an introduction to the orchard area and the use of the iNaturalist app at a "base camp", self-guided orchard walks, bird walks with an ornithologist, hands-on biodiversity demonstrations at expert stations and food, drinks, music, and kids' play at the base camp. Figure 2 provides a few illustrative examples from the event.

Figure 2. Walking tour map and stickers (left); Participant group looking at ground life (middle); *Gonepteryx rhamni* caught and later released (right).

[5] https://www.wormsurvey.org/
[6] https://www.inaturalist.org/

BioBlitz outcomes

Over 250 people joined the BioBlitz. About 55 actively used and contributed observations via the iNaturalist app, despite poor network connection in the area. Along the Ramborn Orchard Hiking trail, 87 observations had been recorded on iNaturalist before the BioBlitz. During the BioBlitz, 773 observations were recorded (Figure 3), out of which more than 320 have become iNaturalist "research grade" and now qualify to be included in the global open biodiversity database GBIF[7]. Further analysis of the data, such as comparison with structured FRAMEwork monitoring results and complementarity analysis is planned to be conducted later in 2022.



Imagery ©2022, CNES / Airbus, European Space Imaging, GeoBasis-DE/BKG, GeoContent, Maxar
iNaturalist. Available from https://www.inaturalist.org/observations?place_id=181460 Accessed [16-05-2022]

Figure 3. Area of Luxembourg farmer cluster with biodiversity observations taken in a four-year period before the BioBlitz (left) and records taken during the two-day BioBlitz (right).

At the event, participants were asked to provide feedback via evaluation sheets. Anecdotal feedback was gathered by the authors. Responses indicate that all actors experience gains and benefits from participating in these collaborative activities and awareness of the understanding of agro-biodiversity is strengthened. Actor-specific benefits and gains include, amongst others, knowledge gains and contribution benefits (wider public), accomplishment of public mandate and expanded network (national/local initiatives) and market value gains through being perceived as acting for biodiversity (local businesses).

Challenges and outlook

While the BioBlitz was successful with the wider public, it lacked engagement of local cluster farmers. More efforts need to be made to understand farmer motivation to participate and to tailor suitable offerings. The combination of the opportunistic, unstructured BioBlitz data with streamlined project monitoring following a rigid scientific protocol needs to be examined to understand the scientific potential for farmer cluster analysis. Empowering farmer clusters to function as local systems in a self-sustaining way is essential. While some of the organising partners plan to run similar BioBlitzes in the years to come, local capacity needs to be strengthened to allow sustainability of such activities.

[7] https://www.gbif.org/

Acknowledgements

We thank all FRAMEwork partners and contributors, as well as all BioBlitz participants. FRAMEwork received funding from the European Union's H2020 research and innovation programme under grant agreement No. 862731.

References

Dudley, N. and Alexander, S. 2017: Agriculture and biodiversity: a review. Biodiversity 18: 45-49.

Pocock, M. J. O. et al. 2018: A Vision for Global Biodiversity Monitoring With Citizen Science. Adv. Ecol. Res. 59, 169-223.

Shirk, J. L. et al. 2012: Public Participation in Scientific Research: a Framework for Deliberate Design. Ecol. Soc. 17(2): 29.

Session Projects

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 51-55

The BEESPOKE project: increasing wild pollinators and crop pollination

John M. Holland[1], Dirk Albach[2], Jojanneke Bijkerk[3], Lucy Capstick[4], Michelle T. Fountain[5], Iain Fraser[6], Jendrik Holthusen[7], Jan Jensen[8], Lotta Fabricius Kristiansen[9], Hans Kroodsma[10], Jan-Willem van Kruyssen[11], Helle Mathiasen[12], Ivan Meeus[13], Lene Sigsgaard[14], Arjen Strijkstra[15], Frank Stubbe[16], Thomas van Loo[17], Atle Wibe[18]
[1]Freelance/BEESPOKE project coordinator, UK; [2]Carl von Ossietzky Universität Oldenburg, Germany; [3]Cruydt-Hoeck, Netherlands; [4]Game and Wildlife Conservation Trust, UK; [5]NIAB East Malling, UK; [6]University of Kent, UK; [7]Grünlandzentrum Niedersachsen / Bremen, Gerrmany; [8]Kiviks Musteri AB, Sweden; [9]Sveriges Lantbruksuniversitet, Sweden; [10]Agrarisch Collectief Waadrâne, Netherlands; [11]Freelance/Provincie Fryslân, Netherlands; [12]HortiAdvice Scandinavia A/S, Denmark; [13]Ghent University, Belgium; [14]University of Copenhagen, Denmark; [15]Van Hall Larenstein, Netherlands; [16]Vlaamse Landmaatschappij, Belgium; [17]Inagro VZW, Belgium; [18]NORSOK, Norway*

Abstract: The Interreg North Sea Region of Europe is one of the most productive agricultural areas, but has been identified as having low pollination potential. The BEESPOKE project aims to encourage land managers to conserve wild insect pollinators through demonstrating their value for crop production and by providing tools to create more pollinator resilient landscapes. The tools include improved knowledge about the best pollinators for crops, seed mixes tailored to their support, protocols for estimating pollination, training materials, how agri-enviroenment can be improved and a novel landscape model to identify where resources are best placed.

Key words: pollination, pollinators, bees, agri-environment, field margins, agro-ecology

Introduction

Insect pollination is worth €15 Billion in the EU, however, wild pollinators are declining because of loss in flower-rich habitats. The Interreg North Sea Region (NSR) of Europe is one of the most productive agricultural areas, but was identified as having low pollination potential (Zulian et al., 2013). Pollination is essential to ensure optimum yields and quality of some crops. The abundance of wild bees shows strong linear correlations with the amount of floral resources, yet despite this knowledge and the opportunity in NSR countries to increase areas of flower-rich habitat through agri-environment measures (AEMs), land managers are not widely adopting conservation practices. In 2019, the BEESPOKE project (Benefitting Ecosystems through Evaluation of food Supplies for Pollination to Open up Knowledge for End users) started with the main aim of increasing levels of pollinators and crop pollination at local and landscape scales by providing land managers and policy makers with new expertise, tools and financial knowledge to create more sustainable and resilient agroecosystems though improved conservation of insect pollinators. The project includes partners from all of the NSR countries and investigates arable and horticultural crops, along with florally diverse grassland.

Approaches

At present the focus of actions is on increasing pollinators for their conservation with less effort on increasing their contribution to crop production (Fountain, 2022). The main remit of the project is to therefore improve our understanding of the benefits of supporting pollinators for a wide range of crops and to impart this knowledge to farmers so that they may have an extra incentive to implement pollinator conservation practicies.

Enhancement of floral resources
There is good evidence that the establishment of new wildflower habitat can increase wild bees (Fountain, 2022) and such an approach is supported, to varying extents, through agri-environment schemes in NSR countries. However, because crops differ in the type of pollinators needed because of differences in their flower structures, more targetted wildflower seed mixes are needed to support the most appropriate pollinators. One of the key aims of the BEESPOKE project is to support pollinators for a range of crops across the NSR. We are testing the effectiveness of the new mixes by planting flower-rich areas in close proximity to a range of crops (apples, plums, sweet cherries, strawberries in polytunnels and outdoors, raspberries and in arable areas) using a network of pilot farms in each participating country. To date we have established new wildflower areas at 76 locations.

Measuring levels of pollinators and pollination
There are still knowledge gaps regarding the extent to which flowering crops benefit from insect pollination and evidence that there are deficiencies for some crops resulting in substantial economic consequences. Another key aim of the project is to fill knowledge gaps and develop farmer friendly methods for assessing levels of pollinators and pollination, so that this can become routine practice. Investigations have been conducted in apples, pears, plums, sweet cherries, strawberries, raspberries and field beans. A protocol for measuring pollinators and pollination in apple and pears has been produced. Measuring pollinators and other beneficial insects can be time consuming and biaises occur depending on the method, therefore a range of methods are being tested.

For field beans *Vicia fabae* a range of protocols have been tested (exclusion, hand and trigger pollination) to evaluate the impact of pollination on bean yields, however, results have been highly variable and variety dependent. Flower strips may only have a very local impact on levels of pollinators and pollination, therefore the distance over which effects can be detected are being investigated in apples, strawberries and arable crops. To date, there was only limited evidence that levels of some pollinators declined with distance from the flower strips, in apples, but not berry crops.

Most flowering wild plants also rely on insect pollination, yet whether this is adequate is poorly understood. Studies will be conducted in 2022 to measure levels of pollination in hawthorn.

A protocol for identifying the main groups of pollinators and measuring their numbers has been produced. Two more detailed guides to identifying the common species of bumblebee and solitary bees are also now also freely available on the project website.

Management of flower-rich habitats
For those that have tried establishing wild-flower habitats this can sometimes be a frustrating business, with poor results. The species that germinate will often depend on local conditions and so we are working closely with seed producers to increase the chances that our bespoke seed mixes will deliver what is expected. To improve the success and quality of such habitats

the project is providing training and advice to ensure optimal habitats are created. A simple guide on how to establish wildflower areas has been produced and includes common mistakes. Besides sown mixes, other habitats typically found on farmland can also support pollinators, such as hedgerows, woodland and low input grassland, and a booklet has been produced on how to manage these.

Forage crops such as alfalfa and grassland can also provide huge floral resource if allowed to flower. A phased mowing regime for alfalfa has been developed. In grassland, four floristically diverse seed mixes are being evaluated.

Table 1. Partner involvement in the project

Partner	Activities
GWCT, UK	Lead partner, field bean & hawthorn pollination, seed mixes for alongside ditches, bumblebee & solitary bee guides
Carl von Ossietzky Univ. Oldenburg, Institute for Biology and Environmental Sciences, D	Development of herb-rich grassland mixes
Cruydt-Hoeck, NL	Wildflower seed producer, advice on seed mixes, establishment & management
NIAB East Malling, UK	WP lead, testing new seed mixes, fruit and berry crop pollination, protocols, demonstration sites, training
Univ Kent, School of Economics, UK	Economics and barriers to farmers
Grünlandzentrum Niedersachsen, D	Farmer training grassland mixes
Kiviks Musteri, SE	Commercial orchard, demonstration and knowledge exchange
Sveriges Lantbruksuniversitet, Department of People and Society, SE	WP lead for monitoring and evaluation
Agrarisch Collectief Waadrâne, NL	Demonstration sites
Freelance/Provincie Fryslân	WP lead communications
HortiAdvice Scandinavia, DK	Demonstration sites and knowledge exchange
Ghent Univ., Dept. of Plant Protection, BE	Development of models, testing new seed mixes, fruit crop pollination
Univ. Copenhagen, Dept. Plant and Environmental Sciences, DK	WP lead, testing new seed mixes, fruit and berry crop pollination
Van Hall Larenstein univ. of applied sciences, NL	Testing new seed mixes, arable crop pollination, novel crops, monitoring methods
Vlaamse Landmaatschappij, BE	WP lead for policy, AEMs and SWOT analysis
Inagro VZW, BE	Testing new seed mixes, arable crop pollination, novel crops, alfalalfa
NORSOK, NO	Testing new seed mixes and raspberries pollination

Landscape management

Some pollinators are very mobile capable of flying several to many kilometres and the provision of floral resources across the landscape needs consideration. To aid in this process new models have been developed to predict levels of pollination for incorporation into a farmer-friendly online tool. The model uses existing land use data and from this estimates the forage and nesting suitability for a range of bee species and whether a nest can be established. The foraging range of the bee species is also considered. These values are then used to predict the likely pollination service for different crops. The tool will also be valuable for government agencies to facilitate landscape planning to support pollinators. A further tool to aid the design of seed mixes tailored to local conditions and target pollinators is also planned.

Improving agri-environment policy
If pollinators are to be better conserved it is essential that AEMs provide the right support. The AEMs in each partner country have been reviewed and a draft report completed. In addition, SWOT analyses are underway working with key relevant parties to identify how to improve existing AEMs.

If farmers are to implement measures to support pollinators they will want to know the financial implications. Indeed, costs may already be a barrier for many. A survey has therefore been conducted to better understand why farmers are not implementing activities to support pollinators and to understand the cost implications of such actions.

Knowledge exchange
To enure project findings are widely implemented, a comprehensive range of knowledge exchange activities are underway. We know that farmers respond best to in-field training events therefore these are being conducted or are planned at the demonstration sites to help in their understanding of pollinators crop pollination and management of flower-rich habitats. These are supported by provision of training materials and online vidoes. We are using traditional and social media to generate additional interest and produce our own newsletter as well as contributing to others. Findings relating to policy will be promted to relevant national agencies.

Project evaluation
The project combines many different elements as we are conducting novel research and providing an extensive knowledge exchange process. To aid this a comprehensive monitoring and evaluation, activities are being conducted to measure the success of the various elements and provide guidelines for future projects.

Discussion

Insects are declining globally and include many species and groups of pollinators. Given their importance for food security it is essential that we communicate the importance of this to land managers that can have a direct influence, whilst also providing them with the tools and knowledge to achieve change. The project is attempting to identifying the economic importance of pollination and to provide practical solutions for farmers. Demonstration activities and provision of practical advice is an important part of this process yet is often lacking in research projects. The Interreg programme is proving value as there is a strong emphasis on communication and instigating change and provides the support to link research and knowledge exchange.

Acknowledgements

BEESPOKE is carried out in the framework of the Interreg. North Sea Region Programme (www.northsearegion.eu) under the Programme Priority 3 “Sustainable North Sea Region” and the Specific Objective 3.2 “Develop new methods for the long-term sustainable management of North Sea ecosystems”. The programme is funded by the European Regional Development Fund (ERDF) of the European Union.

References

Fountain, M. T. 2022: Impacts of Wildflower Interventions on Beneficial Insects in Fruit Crops: A. Review Insects 13: 304.

Zulian, G., Maes, J., Paracchini, M.-L. 2013: Linking land cover data and crop yields for mapping and assessment of pollination services in Europe. Land 2: 472-492.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 56-60

Bees: how and what to monitor to convey critical information

Manuela Giovanetti[1], Amanda Dettori[1], Elena Cargnus[1], Elena Tafi[1], Valeria Caringi[1], Laura Bortolotti[1]
[1]*CREA Research Centre for Agriculture and Environment, Via di Corticella n. 133, 40128 Bologna, Italy*
E-Mail: manuela.giovanetti@crea.gov.it; laura.bortolotti@crea.gov.it

Abstract: While the future of agricultural ecosystems is under review, bees are labelled as good indicators of environmental quality. However, the terms of bee monitoring at a large landscape scale are largely underestimated. In Italy, we are carrying out a project to monitor honey and wild bee conditions in agro-ecosystems at the national level. The underlying structure of such an ambitious project is presented, with the first feedback and issues.

Key words: honeybees, wild bees, monitoring, agricultural landscape

Introduction

Nowadays the concern on the decline of pollinators raises the attention of both, a multidisciplinary research audience and the public. Among pollinators, bees are certainly the main target in temperate areas and concerns about their diversity and abundance need to be finally tackled. The environment is expected to be the key to disentangling local decreases.

Healthy environments for bees may not be coincident with agro-ecosystems, that often include critical practices as habitat fragmentation, pesticides use, tillage, etc. Therefore, to assess links underneath the pollinator crisis we need to tackle the landscape scale (Giovanetti et al., 2021). Scientific monitoring is a powerful tool to assess the current conditions of a species, a functional group, or a given environment. When carefully designed, it can be used to implement basic information, investigate correlations, address unsolved questions, and build a network of stakeholders (Elzinga et al., 2001).

In Italy, a project on scientific monitoring on bees exists: BeeNet (Giovanetti and Bortolotti, 2021) specifically addresses the above issues, by building a country-wide network that will record bee health, abundance and diversity, and engage stakeholders such as beekeepers, natural park managers, farmers and policymakers along the three years of the project. A project on scientific monitoring requires a constant commitment on two sides: the management of a structured network to secure the data gathering, and the update and elaboration of the results, including their acknowledgment in different contexts. We briefly illustrate BeeNet structure and preliminary achievements.

Materials and methods

The operational structure

A conspicuous amount of time was invested in defining the operational structure of the project (Figure 1). After building a strong team of experts and qualified technicians, clusters of topics have been identified for the two conceptual frameworks (i. e. honeybees and wild bees, details below). The two frameworks may coincide in few elements; however, they differ substantially due to 1) the honeybee being a managed species and with a large literature on its biology and 2) the wild bees being a large group with common and rare species, often with poor literature on their biology and distribution. Moreover, differences exist in the type of samples to be collected and related protocols, including transfer to the laboratory for morphological and molecular identification; in the stakeholder groups to be involved; in the dissemination design. Encompassing all the above, there is the landscape scale: a **national** monitoring implies to be inclusive of bureaucratical fragmentation (e. g. the level at which the decision-making process takes place, for what concerns regulation and fundings); a **bee monitoring** implies the interpretation of cartographic information at adequate levels of resolution (e. g. flight range, landscape features).

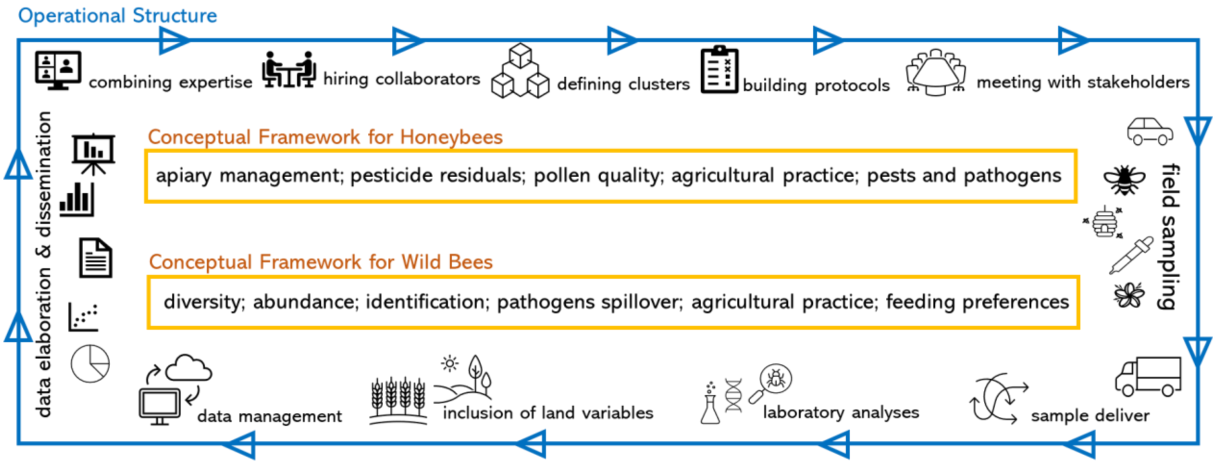


Figure 1. Mind map of BeeNet project. The two orange boxes in the centre refer to the conceptual frameworks adopted for investigating honeybees and wild bees in Italy; the blue box refers to the operational structure needed to carry out the investigation and deliver the results.

The conceptual framework for honeybees

The monitoring focuses on colony growth and health (pests and pathogens; apiary management); food conditions (pollen quality, environment surrounding the apiary). A network of apiaries is the matrix generating samples for all analyses. Stationary apiaries have been selected on the entire country, after seeking collaboration with stakeholders (beekeepers' associations and their members) and by exploring their location through cartographic databases; samples and data are gathered according a delivered BeeNet protocol. Bee forager samples are gathered four times a year, pollen samples two times a year; we ensure the necessary thermal conditions of samples from the field (portable cooler) to the laboratory (-20 °C to prevent DNA degradation). In the laboratory, bee foragers are analyzed for pathogen survey, pollen samples for nitrogen content and pesticide residues. Information from beekeepers/technicians on apiary management and colony growth (direct records in the field) are then digitalized; information on resulting laboratory analyses is returned to associations' members in compliance with confidentiality agreements.

The conceptual framework for wild bees

The monitoring focuses on species diversity, distribution and feeding preferences. The Corine Land Cover inventory helped in the definition of two opposed environments, where transects have been established: with intensive or semi-natural agricultural features. We placed a 200 m × 2 m transect for each agro-environmental system in each of 11 Italian regions. Monthly monitoring will provide wild bee samples and report individual interaction with the plant species: each transects is walked in 1-hour time, bees collected in the transect are reported if visiting a given plant (when catch on the flower, the latter identified by the app PlantNet) or recorded as "flying". More information is collected on plant species, as their abundance. Bee samples are dry-prepared after some material has been saved for barcoding; all specimens are transferred for identification at the taxonomic laboratory, where specialists ensure species-level classification. Information on the flora is digitalized, while problematic identification of plant species will undergo the validation of an expert botanist on the dry sample material.

Results and discussion

The operational structure

The main result of the operational structure behind BeeNet is the wide network of sites that will deliver data on honeybees (Figure 2, left) and wild bees (Figure 2, right). The employment of CLC inventory allowed a national landscape perspective, that may help future comparison with other countries. However, since bee flight ranges are at a lower extent of resolution, the project will later include landscape analyses based on diverse/local inventories of soil use and vegetation-based descriptors. The first active year of the project was very important to define pitfalls and obstacles in the operational structure.

Figure 2. Maps of BeeNet site distribution in Italy: on the left, apiaries position reporting honeybee colonies growth and health (each yellow dots refer to an apiary with five colonies under BeeNet constant control); on the right, transects where wild bee diversity and distribution is investigated (green dots indicate semi-natural agro-environments; orange dots indicate intensive agro-environments).

The conceptual framework for honeybees

The network of apiaries resulted in 351 sites and 1755 honeybee colonies monitored. Stakeholders comprise three national beekeeper associations with their regional associates in Italy, ensuring wide participation and dissemination of results. Such a large network encountered some problems in sample delivery (from a minimum of 7.7 % of a maximum of 44.9 % of expected samples): missed samples (no samples, or from a reduced number of apiaries, or scarce material); mistaken transfer of samples/data (missed agreement with the carrier, discontinuity in the cooling chain, wrong identification of the site, incomplete protocol sheets); undefined. Solutions are currently sought through meetings with associations and operators. Some delays also occur in sample analyses, mainly related to the COVID pandemic that delayed staff recruitment and laboratory equipment delivery. Notwithstanding, preliminary molecular analyses indicated a conspicuous incidence of the Deformed Wing Virus (DWV), of the Chronic Bee Paralysis Virus (CBPV) and of *Nosema ceranae*. Less frequent seems the incidence of the Acute Bee Paralysis Virus (ABPV) and of the Kashmir Bee Virus (KBV), while *Lotmaria passim* emerged on the Tyrrhenian sites.

The conceptual framework for wild bees

The network for wild bees finally comprises 24 sites. Selection of site is the outcome of a large discussion among experts, and finally integrates information on soil use as in CLC inventory, but also elevation (reduction of species number), proximity to a protected area (possible reservoir-effect), and the existence of previous monitoring data. Stakeholders comprise colleagues at four local universities, helping with field data collection, and park managers. The COVID pandemic heavily affected this part of the project, due to restrictions on travel across the country. When data collection started some delays in sample transfer and analyses were recorded. For the data, mistakes were mostly linked to misinterpretation of protocol procedure, but also unknown reasons for the delay should be accounted for. The analysis-related issues are strictly linked to sample transfer and to the intrinsic difficulty of taxonomy. To date, 4123 specimens reached the laboratory, 61.14 % (n = 2521) of which has already been identified and found to belong to 38 genera. Plant-pollinator networks, including plant and bee traits, are under construction.

"How" to investigate may appear an easy task for a well-known species, such as the honeybee, or for wild bees for which various monitoring methods have already been applied at various scales. However, "how" is challenging in a project whose ambition is to integrate a national landscape approach and local stakeholders (Oguro et al., 2019). The operational structure is a mechanism that needs to be tuned and this step requires a time slot usually neglected. A good operational structure will ensure fluent and constant data for the conceptual framework, also by managing the "what"-to-monitor question and the complexity behind the data collection.

Acknowledgements

We are indebted to the BeeNet team and external collaborators. BeeNet (2019-2023) is funded by MIPAAF (Ministry for Environment, Land and Sea through FEASR 2014-2020 funding).

References

Giovanetti, M. and Bortolotti, L. 2021: Report on a project: BeeNet at the start. Bull. Insectology 74(2): 284.

Giovanetti, M., Albertazzi, S., Flaminio, S., Ranalli, R., Bortolotti, L., and Quaranta, M. 2021: Pollination in Agroecosystems: A Review of the Conceptual Framework with a View to Sound Monitoring. Land 10 (5): 540. DOI: 10.3390/land10050540.

Elzinga, C. L., Salzer, D. W., Willoughby, J. W., and Gibbs, J. P. 2001: Monitoring plant and animal populations: a handbook for field biologists. Blackwell Science Ltd, UK.

Oguro, M., Taki, H., Konuma, A., Uno, M. and Nakashizuka, T. 2019: Importance of national or regional specificity in the relationship between pollinator dependence and production stability. Sustain. Sci. 14: 139-146.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 61-65

FRAMEwork: a system-wide approach to biodiversity sensitive farming in Europe

Graham S Begg[1], Niamh McHugh[2], Gerid Hager[3], Camilla Moonen[4], Lisette Cantu Salazar[5], Stefanie Engel[6], Benedetto Rugani[5], Alastair J Simmons[7], Beatrix Keillor[1], Fanny Tran[1], and John Holland[2]
[1]The James Hutton Institute, Invergowrie, Dundee, DD2 5DA, Scotland; [2]Game and Wildlife Conservation Trust, Fordingbridge, England; [3]International Institute for Applied Systems Analysis, Schlossplatz 1, 2361 Laxenburg, Austria; [4]Scuola Superiore Sant'Anna, Pisa, Italy; [5]Luxembourg Institute of Science and Technology, 5 avenue des Hauts-Fourneaux, 4362 Esch-sur-Alzette, Luxembourg; Osnabrück University Institute of Environmental Systems Research Barbarastr. 12, 49076 Osnabrück, Germany; [7]Taskscape associates LTD, Carlisle, England

Abstract: FRAMEwork is a dynamic response to the global biodiversity crisis that, despite international recognition of the critical environmental threat, sees biodiversity loss continuing at an alarming rate. In Europe, where agriculture accounts for c. 40 % of land use, conserving farmland biodiversity is critical to countering the biodiversity crisis. At the same time, there is an urgent need to increase the efficiency and sustainability of agriculture to feed the growing global human population (a 60 % increase in agricultural production is required by 2050). FRAMEwork's vision for biodiverse, sustainable, and efficient agroecosystems is delivered via a novel and comprehensive package – the FRAMEwork System for Biodiversity Sensitive Farming – comprising all the components necessary to generate and deliver an ecologically sound, technically robust, and socio-economically desirable solution to biodiversity sensitive farming for long term resilience in European agriculture. FRAMEwork's multi-actor, farmer-led and landscape scale approach to biodiversity management goes beyond the state-of-the-art in stakeholder co-innovation and will have a legacy beyond the project lifetime. FRAMEwork will: champion the multi-actor approach with Advanced Farmer Clusters and their extensions to Cluster Working Groups as the primary instrument for the practical delivery of biodiversity sensitive farming; implement novel landscape ecological studies to inform farmland biodiversity management; develop innovative methods and tools for biodiversity management, monitoring and evaluation; influence policy development by designing incentives for biodiversity sensitive farming; devise a new system-wide evaluation of biodiversity sensitive farming; and influence EU agriculture long-term by constructing a Citizen Observatory and Information Hub adding to a legacy that will support everyone with an interest and stake in farming and biodiversity.

Key words: biodiversity, agriculture, farming, landscape, collective, Horizon 2020

Introduction

Biodiversity is essential for agro-ecosystem resilience, sustainability, and long-term food security (Seppelt et al., 2021), yet agriculture has been a significant contributor to the global decline in biodiversity (Dudley and Alexander, 2017). Typically, management for short-term economic returns has taken priority over management for the environment (Rayner et al., 2008) and neither alternative approaches to conventional agriculture (e. g. organic or integrated farming) nor legislation (e. g. Common Agriculture Policy, Sustainable use of Pesticides Directive, Water Framework Directive) have proved effective in mitigating these adverse effects. Current mechanisms for compensating and encouraging farmers to apply biodiversity sensitive management strategies are often inefficient with low levels of adoption. They are typically applied at individual farm rather than landscape level, and tend to be generic solutions, imposed from the top down in the form of governmental regulation. Monitoring is rarely carried out and there is therefore little scope for evaluating the success of strategies in achieving improvements to farmland biodiversity. A new approach to the design, implementation and monitoring of biodiversity sensitive farming is therefore urgently required. Responding to this, the FRAMEwork project represents a novel initiative blending research and innovation with the aim of creating a comprehensive package comprising the components necessary to generate and deliver an ecologically sound, technically robust, and socio-economically desirable solution to biodiversity sensitive farming in Europe.

Aims

The primary purpose of the FRAMEwork project is to create an approach or system that could be used to facilitate a transition to biodiversity sensitive farming that can support biodiversity and benefit from the provision of enhanced ecosystem services, while mitigating potential agronomic or economic risks.

The **FRAMEwork System for Biodiversity Sensitive Farming** combines the following elements:

- **Advanced Farmer Clusters** – local farmer groups working as a collective to deliver landscape scale management, supported by a Cluster Facilitator with expertise in agriculture and the environment, and linked to a Cluster Stakeholder Group to inform and promote policy and practice, organised into regional, national, and international networks.
- **Technical Resource** – specialists associated with the regional, national, international networks to provide technical information, methods, and tools to support agrobiodiversity monitoring, management and policy including the dedicated decision support tools.
- **Scientific Innovation** – researchers associated with regional, national, international networks to provide knowledge on the ecology, sociology and economics that underpins the functioning of sustainable agricultural systems.
- **Citizen Observatory and Information Hub** – an open access platform to support FRAMEwork networks and Communities of Practice: sharing activities, information, data and resources between farmers, scientists, policy makers, and citizens.

Materials and methods

To deliver on this purpose the FRAMEwork project will design, build, test, and deploy a prototype of the FRAMEwork System for Biodiversity Sensitive Farming following a plan of work structured into a set of six interacting research and development work packages (Figure 1).

The project is built around a series of place-based, pilot studies and will follow the progress of more than one hundred farmers as they make the transition to biodiversity sensitive farming through the implementation of the Advanced Farmer Cluster approach (WP2). The pilot studies support the co-design and testing of integrated solutions to support biodiversity, drawing on local knowledge of agricultural practice, biodiversity, and the agroecosystems and agri-food systems in which they are placed. They span the range of European farming experiences and cover a wide range of biodiversity foci and related ecosystem functions.

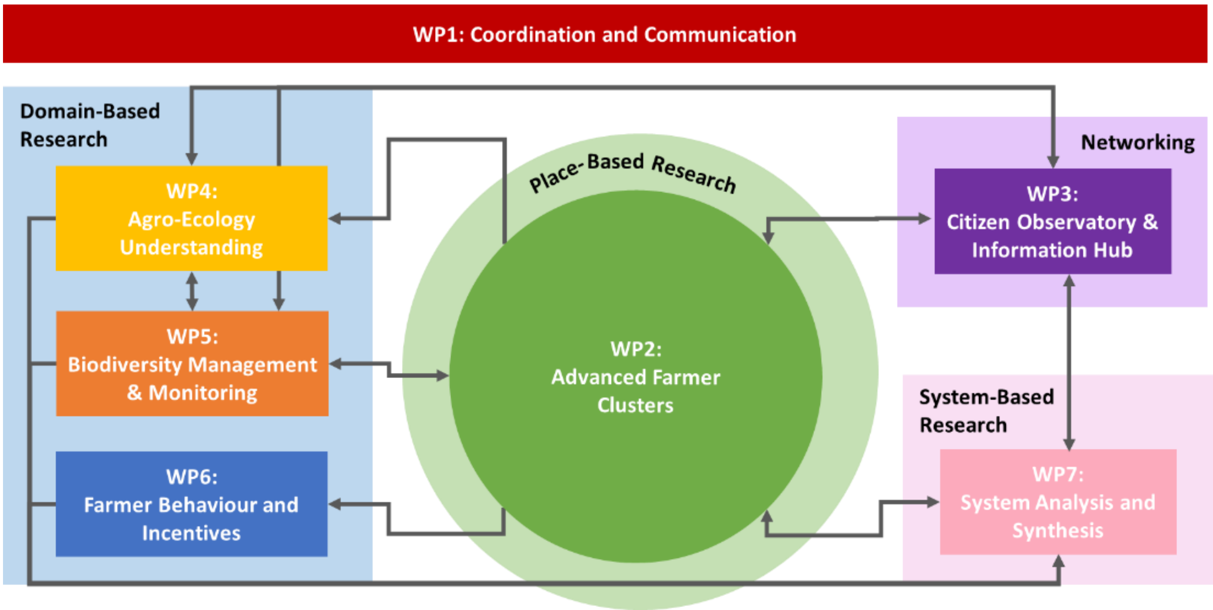


Figure 1. Flow of information and knowledge in FRAMEwork.

In addition, the pilot studies will fulfil the function of place-based living labs (www.openlivinglabs.eu) providing a platform for scientists and other experts to combine and elaborate their investigations in a real-world, multi-disciplinary context for the development of practical applications in support of biodiversity sensitive farming. This approach is being used to create a deeper understanding in key areas: the ecology of farmland biodiversity (WP4); the development of biodiversity sensitive farming practice and biodiversity monitoring (WP5); and the attitude and behaviour of farmers and the role of incentivisation (WP6). In return, through the transdisciplinary approach, FRAMEwork will enable more of Europe's citizens (farmers, businesspeople, policy makers, general public) to appreciate and contribute to the future of farming as custodians and beneficiaries, not just of production, but of biodiversity, ecosystem services and the environment. This will be promoted by the expansion of the Citizen Observatory concept (https://citizen-obs.eu/) into a European Citizen Observatory and Information Hub (WP3), an integral component of the FRAMEwork System alongside the Advanced Farmer Clusters, to share data and knowledge between citizens and institutions, combining their contributions to support design, testing and decision making in biodiversity sensitive farming. FRAMEwork will ally insight gained from transdisciplinary activities with social-ecological analysis and natural capital accounting approaches to evaluate the overall functioning, performance, and the impact of the Advanced Farmer Clusters and the FRAMEwork System (WP7). By synthesising knowledge across a wide range of pedo-climates and socio-economic conditions, this approach will allow scenarios beyond the model Pilot Studies to be explored and the application of the FRAMEwork System in Europe-wide and global contexts to be assessed.

Results and discussion

At the time of writing, FRAMEwork has been in progress for a little more than eighteen months. During this time, 11 farmer clusters have been established including the appointment of Cluster Facilitators. The Clusters have identified their biodiversity concerns and are introducing new approaches to tackle these. In parallel, progress has been made in the development of a decision support tool to support agrobiodiversity management and monitoring. Working with the clusters, end-users and their requirements have been defined, target biodiversity and ecosystem-service impact categories identified, and appropriate metrics and indicators established.

Standardised biodiversity monitoring protocols have been trialled and are now being implemented across all clusters as part of the evaluation of their impact on biodiversity. This evaluation will be extended to include a sustainability assessment and relevant indicators have been defined with standard operating procedures prepared for their collection and measurement. In addition, farmers and facilitators have begun training in biodiversity monitoring, and facilitators are being supported in the co-development of farmer-focused monitoring approaches, while barriers and opportunities for engaging farmers and farmer families in monitoring have also been explored. The first public event, a BioBlitz at the Luxembourg cluster (https://www.inaturalist.org/projects/city-nature-challenge-2022-luxembourg/journal), was successful in raising the awareness of public to the issues of biodiversity and farming while delivering the first citizen-based biodiversity observations for the project. Planning for similar events involving school groups and farming communities is now underway.

The Citizen Observatory and Information Hub is in development with building blocks for the online cluster network being developed, including map visualisation, profile pages, log-in functionality, and admin dashboard and interface for platform management, as a support to both farmer and facilitator communities of practice. The project communication strategy seeks to drive multi-actor engagement and also build audiences for the info. To this end, a project-website has been built (http://www.framework-biodiversity.eu/) and maintained in concert with a range of other communication tools including social media, blogs, and podcasts.

We are learning from this work that the attitudes of the farmers are a key determinant of the development of the clusters and that they vary substantially within and between clusters. Surveys and interviews are underway to formally evaluate this and explore the evolution of attitudes through cluster participation and the benefits of positive reinforcement. FRAMEwork is actively developing support mechanisms which will offer a soft incentive to motivate farmers and is also working on the design and evaluation of economic incentive schemes. However, for the participatory approach to be effective, the benefits of research from across the project need to be accessed early by the farmers, and probably repeatedly through the lifetime of the project. Therefore, the potential to use preliminary results to support the clusters is being actively pursued in the expectation that it will promote their transition to biodiversity sensitive farming systems.

Acknowledgements

Thanks go to all FRAMEwork partners and contributors, particularly the members of the Advanced Farmer Clusters. FRAMEwork received funding from the European Union’s H2020 research and innovation programme under grant agreement No. 862731.

References

Dudley, N. and Alexander, S. 2017: Agriculture and biodiversity: a review. Biodiversity 18: 45-49.

Rayner, G., Barling, D. and Lang, T. 2008: Sustainable Food Systems in Europe: Policies, Realities and Futures. Journal of Hunger and Environmental Nutrition 3: 145-168.

Seppelt, R., Arndt, C., Beckmann, M., Martin, E. A. and Hertel, T. W. 2020: Deciphering the Biodiversity – Production Mutualism in the Global Food Security Debate. Trends in Ecology and Evolution 35: 1011-1020.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 66-70

Farmer Clusters: A FRAMEwork for connecting conservation measures in agricultural landscapes

Niamh M. McHugh[1], Ellie Ness[1], John Holland[1], Clare Buckerfield[2], Jürgen Friedel[3], Aliyeh Salehi[3], Walter Starz[4], Daniela Ablinger[4], Eve Veromann[5], Riina Kaasik[5], Carlos Sánchez[6], Gonzalo Varas[6], Pauline L'hote[7], Pierre Frank[7], Francois Warlop[8], Virginia Bagnoni[9], Simone Marini[9], Camilla Moonen[9], Marco Beyer[10], Youri Martin[10], Sarah Vray[10], Paul van Rijn[11], Lennard Duijvestijn[11], Iris Bohnet[12], Jan Travnicek[12], Kristina Janečková[13], Gill Banks[14], Alastair Simmons[15] and Graham Begg[14]

[1]Game and Wildlife Conservation Trust, Fordingbridge, England; [2]Farming and Wildlife Advisory Group South West, Wellington, England; [3]The University of Natural Resources and Life Sciences, Vienna, Austria; [4]Agricultural Research and Education Centre, Raumberg, Austria; [5]Estonian University of Life Sciences, Tartu, Estonia; [6]Fundación Artemisan, Ciudad Real, Spain; [7]Group Research Agriculture Biological, Avignon, France; [8]National Research Institute for Agriculture, Food and the Environment, France; [9]Scuola Superiore Sant'Anna, Pisa, Italy; [10]Luxembourg Institute of Science and Technology, Luxembourg, Luxembourg; [11]University of Amsterdam, Amsterdam, Netherlands; [12]Czech Organics, Czechia, Czech Republic; [13]Czech University of Life Science Prague, Prague, Czech Republic; [14]The James Hutton Institute, Dundee, Scotland; [15]Taskscape associates LTD, Carlisle, England

Abstract: Across the European Union (EU), 173 million hectares of land is used for agricultural production and due to the use of intensive farming methods this land is a major contributor to ecosystem degradation and biodiversity loss. As a result of this, there is an increasing interest in the development and application of biodiversity sensitive farming systems designed to mitigate for these effects. One emerging solution is the Farmer Cluster concept, a movement which began in 2015 and has grown to encompass over 100 Farmer Clusters in the UK. A 'Farmer Cluster' is a community of farmers, located in the same region, who share knowledge, support and motivate each other to improve biodiversity and the ecological health of their farms. Farmer Clusters have become increasingly popular in the UK, but evidence of the environmental benefits of Farmer Clusters is largely anecdotal. The European FRAMEwork project aims to introduce Farmer Clusters to a further eight European countries, and scientifically evaluate their effectiveness from the outset. The project will also develop this concept further to deliver Advanced Farmer Clusters, in nine countries including England, by providing a new level of technological support to help farmers reach their goals. Here we provide an overview of the history and development of the Farmer Cluster concept along with an overview of FRAMEwork's 11 Advanced Farmer Clusters which represent a range of different farming systems, cultures, and climates.

Key words: agroecology, biodiversity, agri-environment, farmland, conservation

Development of the Farmer Cluster Concept

In 2010 the The Lawton report "Making Space for Nature" was published, this independent review was conducted to identify how the management of England's countryside could be improved to benifit biodiversity in response to increasing environmental pressures, including climate change (Lawton et al., 2010). One of the key concepts presented in this report was that to create a biodiverse rich countryside better protection of non-designated wildlife sites was needed and that habitats needed to be “bigger, better and joined”. This concept was tested in England between 2012 and 2015 through 12 pilot Nature Improvement Areas (NIAs), which were landscape scale initiatives that aimed to improve habitat connectivity and, in turn, biodiversity. Of the 12 NIA’s only one was farmer led, the Marlborough Downs NIA, Wiltshire, England.

The Farmer Cluster concept grew from the develpment of the Marlborough Downs NIA and the Grey Partridge Recovery Project on the Peppering Estate at Arundel, Sussex, England (Ewald et al., 2010; Potts, 2012). The latter project sparked a discussion around the ability of wildlife from ‘hotspot’ farms to spillover onto neigbouring farmland by improving habitat networks (Thompson et al., 2015). From this discussion, the idea was further developed into the ‘Farmer Cluster’ concept in which a community of farmers, located in the same region, share knowledge, support and motivate each other to improve biodiversity and the ecological health of their farms. It is a bottom-up process because farmers decide on their conservaion priorities and how they will be addressed, under the guidance of a facilitator, this is opposed to previously imposed top-down processes for farmland conservation in England such as Countryside Stewarship where environmental priorities were set by Natural England, the government's adviser for the natural environment in England. The Game and Wildlife Conservation Trust (GWCT) presented this idea to Englands Department for Food, Environment and Rural affairs and Natural England as a concept note: “A new approach to farmland conservation – *Farmer Clusters”*. Approval was granted for GWCT to pilot the Farmer Cluster approach to landscape scale conservation project between September 2013 to March 2015. During this period five Natural England pilot Farmer Clusters (Table 1) were established and a further 10 were set up with GWCT involvement (Thompson et al., 2015).

Table 1. Natural England pilot Farmer Clusters trialled in England from 2013 to 2015.

Cluster location	**System**	**Cluster area (ha)**	**Number of farms**
Hampshire	Mixed	3800	6
Sussex	Mainly arable	6500	10
Gloustershire	Mainly arable	4400	10
Northamptonshire	Mainly arable	4000	9
Devon	Permanent grassland	2200	10

From these pilot studies the core steps in the creation of a Farmer Cluster were defined as:

1. Identify a lead farmer to act as the steering member of the Farmer Cluster.
2. Lead farmer to reach out to potential Farmer Cluster members, utilising friendships, business networks and other relationships.
3. Members to select a Farmer Cluster facilitator who is responsible for adminstration tasks, identifying funding opportunities, organising training events, coordinating surverys and creation of habitat management plans.
4. Mapping the Farmer Cluster extent, habitats and information on species present in the area.

5. Instigate meetings of the Farmer Cluster to establish the group's biodiversity targets and priorities, and the changes in farming practice to address these.

The Farmer Cluster movement has expanded to include more than 100 Clusters throughout England, covering 450,000 ha and involving 1,700 farmers and landowners since their inception in 2010 (https://www.farmerclusters.com/). Building on this success, the FRAMEwork project, which began in October 2020, is extending the Farmer Cluster concept with an enhanced focus on tailor-made management of agrobiodiversity, integration of local stakeholders into each Cluster for collaborative design of interventions with multiple benefits, monitoring and evaluation by farmers of the effectiveness of their management solution, and development of relevant incentive schemes. The resulting Advanced Farmer Cluster (AFC) approach will offer farmers:

- autonomy to set their own objectives (problem and solution) and to respond to them with appropriate technical support and know-how;
- encouragement to work collectively to benefit from shared experiences and to tackle biodiversity conservation at an appropriately large scale;
- opportunity to engage with society more widely in reversing biodiversity loss and promoting sustainability in a way that captures and values the central role to be played by farmers.

FRAMEwork is piloting the AFC concept by establishing and coordinating 11 pilot studies (Table 2). This has included helping to establish the Cluster Stakeholder Groups, and overseeing biodiversity management activities, including implementation, monitoring, and evaluation. Standardised methods have been developed for use across the pilot studies to monitor outcomes, including biodiversity, ecosystem services, farm operations and productivity. The Clusters also operate as living-labs, providing 'real-world' platforms for landscape ecological studies to inform the development and testing of methods and tools for the management, monitoring and evaluation of biodiversity; the design of incentives to encourage biodiversity management by Farmer Clusters; and to share information and data for whole-systems assessment. Each pilot study will also be used to instigate change in the region by demonstrating best-practice and inspiring other farmers, and will be linked via an online hub to support the farmer and citizen-based collection and sharing of harmonised, high-quality information on biodiversity and farming. Together this has the potential to establish a self-sustaining and growing Advanced Farmer Cluster Network across Europe.

Table 2. FRAMEwork's 11 European Advanced Farmer Cluster pilots.

Country	System	Main crops/ livestock	No. Farm	Av. Farm size (ha)	Cluster area (ha)	Primary interest of the cluster
Austria	Mixed	Arable crops/ cattle, poultry	6	15-500	2000	Vegetation, Birds, Pollinators
Austria	Permanent grassland	cattle	12	16-40	ca. 300	Birds and grassland plants
Estonia	Arable/ Mixed	Arable	14	225 (11-1135)	3170	Not decided
Spain	Orchard	Olives	7	20-40	350	Red Legged partridge and/or reducing soil erosion
France	Orchard	Apple, pear	8	25-43	ca. 200	Natural enemies, birds through use of boxes, bats, plants between rows
England	Mixed	Arable, beef, sheep, dairy	19	92-1300	8,000	Hedgerows, calcareous grassland, new ponds and restoring existing ones, farmland birds, Barn owls, pollinators, earthworms, soils and arable plants
Scotland	Mixed	Arable/ Mixed	4	80-525	1153	Soil health, pollinators and arable plants
Italy	Orchard	Olives	16	1-5	ca. 100-500	Not decided
Luxembourg	Orchard	Apples, pears	5	10-15	tbd	Pollinators, their nesting opportunities and floral resources with a focus on old fruit varieties
Netherlands	Arable	Potato, Wheat, Onion, Sugarbeet, Carrot, Bulbs	8	60	500	Possibly biocontrol and soil health, not confirmed
Czech Republic	Mixed	Arable land, vineyards, market gardening, grassland	9	313 (50-1200)	2822	Farmland birds

Acknowledgements

Thanks to the FRAMEwork Advanced Farmer Cluster members for their involvement in the project and H2020 for funding the project under grant agreement number 862731.

References

Ewald, J. A., Potts, G. R. and Aebischer, N. J. 2012: Restoration of a wild grey partridge shoot: a major development in the Sussex study, UK. Animal Biodiversity and Conservation 35: 363-369.

Lawton, J. H., Brotherton, P. N. M., Brown, V. K., Elphick, C., Fitter, A. H., Forshaw, J., Haddow, R. W., Hilborner, S., Leafe, R. N., Mace, G. M., Southgate, M. P., Sutherland, W. J., Tew, T. E., Varley, J. and Wynne, G. R. 2010: Making Space for Nature: a review of England's wildlife sites and ecological networks. Report to Defra.

Potts, G. R. 2012: Partridges. Countryside Barometer. New Naturalist Library Book 121. Collins, London.

Thompson, P., Dent, T. and Watts, S. 2015. The Game and Wildlife Conservation Trust Farmer Cluster Pilot Project, Final Report. Report to Natural England.

Session Habitat management

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 72-76

Contributions to biodiversity and integrated pest management from arable margins in Ireland evaluated through carabid populations

R. Earl[1], G. Jackson[1], D. Ó hUallacháin[2], L. Cole[3], A. Evans[4], L. McNamara[2]
[1]University of Edinburgh, Kings Buildings, Edinburgh, UK; [2]Teagasc, Oak Park, Carlow, Ireland; [3]SRUC, Auchincruive, Ayr, UK; [4]SRUC, Kings Buildings, Edinburgh, UK

Abstract: As an island, Ireland has a restricted diversity of insects in comparison to Britain and continental Europe. As such, there is a research gap on the effects of measures introduced to promote biodiversity. This study aims to evaluate five different grass and perennial wildflower mixtures in comparison with a cereal control using a field scale experiment replicated across five sites. Treatments were established in 2016 and 2017, and sampled for insect populations in May 2018 and 2019. Carabid beetles were selected as a representative family. The total abundance, abundance of functional groups by feeding preferences, diversity, and species richness of adult carabids are used to infer how each mixture supported insect populations in the margin and crop and the potential for pest control. Parallel sampling provided information on whether the populations within the adjacent cereal crop were influenced by composition of the margin. The abundance of general predator carabids was higher in the cereal control than the alternative mixes of the margin. However, no difference in abundance, diversity or richness of all carabids specific to margin composition was evident. Diversity indices differed between the margin and adjacent crop, and richness was greater in the crop than grass margin.

Key words: Carabid beetles, arable margins, biodiversity, Integrated Pest Management (IPM)

Introduction

Ireland has approximately 211 species of carabids, in contrast to 350 in Britain (Habitas, 2006). Measures to increase carabid diversity in agricultural landscapes and the use of carabids as pest control in agricultural crops have been researched and evaluated in Britain, and continental Europe but have not been evaluated on the restricted diversity in Ireland. This study examines:

1) Which plant mix in arable margins increases carabid diversity and abundance compared to the non-intervention of a crop to the edge of a field.
2) Whether different plant mixtures support different populations of functional groups.
3) Whether there are spillover effects from margin populations to the adjacent crop, allowing inference on the value that different margin mixes/margin presence contribute to pest control.

Materials and methods

The field margins were established in September 2016 and October 2017. Margins were split into six 40 × 3 m plots, each sown in random order with four tussocky grass-based mixtures, one natural regeneration plot, and a cereal control. The adjoining cereal crops did not receive an insecticide application for the first 24-30 m from the margin edge (Figure 1). Samples were taken for two weeks in May using pitfall traps. Four pitfall traps were set in each margin plot with parallel traps in the crop along the first tramline, 12-15 m into the field from the margin. Damage by wild animals reduced sample availability so contents of one to four of the traps were used as subsamples, with the unbalanced design accounted for in the analysis. The contents were identified to broad taxonomic groups, and carabid beetles to species (Luff, 2007). These species were categorised by feeding preferences as: specialist collembola predators, generalist predators, omnivores, grain preferring omnivores and herbivores (Cole et al., 2002; Sunderland, 2002).

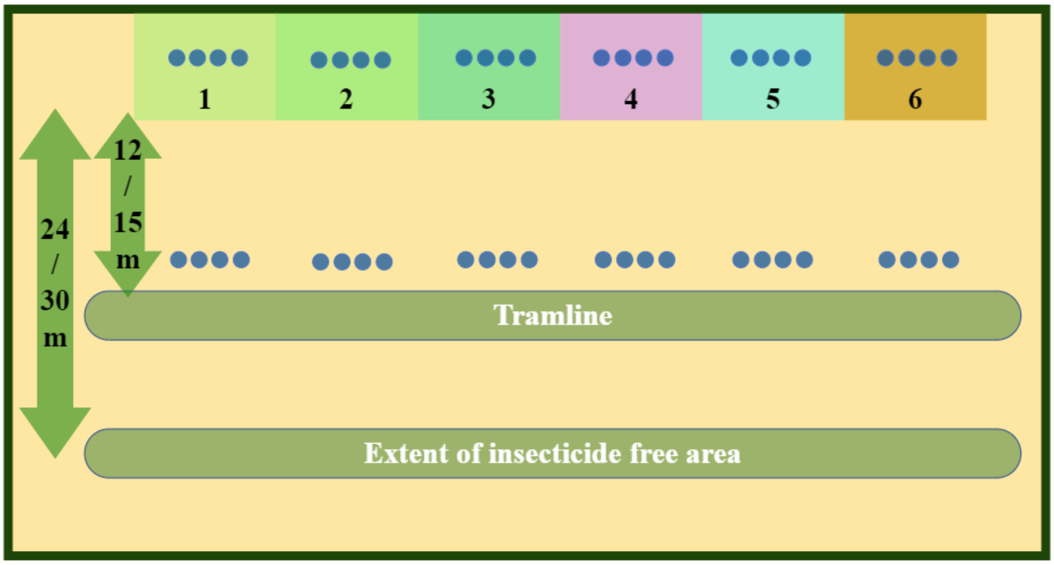


Figure 1. Example margin layout. Sampling in the individual plots and 12-15 m into the crop alongside a tramline. 1-One grass, 2-Two grasses, 3- Four grasses, 4-Four grasses and native perennial wildflowers, 5-Drifting seed and succession from the seedbed for natural regeneration, 6-control (adjoining commercial crop as in the field).

Statistical analyses

Analysis was conducted using R (4.1.2) and the FATHOM package in Matlab. To confirm the field and year groups as random variables a PERMANOVA with Bray-Curtis distances and modified F values (Anderson et al., 2017) was used, to accommodate the unbalanced design and heterogeneous dispersion of the data (Jones, 2014). Zero-inflated Generalised Linear Mixed Models were fitted for the fixed factors of mix, and random factors of field, year and plot with glmmTMB (Magnussen et al., 2017) for separate response variables of abundance (total and per dietary preference group), species richness, and Shannon-Weaver diversity indices produced with Vegan (Okansen et al., 2020). Models were tested with simulated residuals using Dharma (Hartig, 2020).

Results

The analysis of the 'general predators' functional groups is seen in Figure 2. The tramline parallel to the Mix 6 (cereal control) was significantly higher for general predators($p < 0.001$), In the margin, Mix 6 was also significantly higher for general predator abundance($p < 0.001$), and Mix 5, 4, 3, and 2, were significantly lower($p < 0.001$), Species richness was higher in the combined cereal areas (the tramline samples and the cereal control plot) than the combined grassy plots of the margin($p < 0.001$), but higher in the entire margin than the tramline areas ($p < 0.001$). Higher Shannon-Weaver diversity indices were found in the combined grassy margin plots ($p = 0.017$) and the entire margin (including the cereal control) than the combined cereal areas or tramline areas ($p = 0.01$). Shannon-Weaver diversity indices in the margin were significantly lower in Mix 3 (four grasses, $p = 0.038$) and significantly higher in Mix 6 ($p < 0.001$), (the cereal control) while the adjacent crop showed no difference. There were no differences in total carabid abundance or species richness between mixes in the margin and the adjacent crop. The collembola specialists, grain preferring omnivores, omnivores and herbivores were present in too low numbers for analysis to be appropriate.

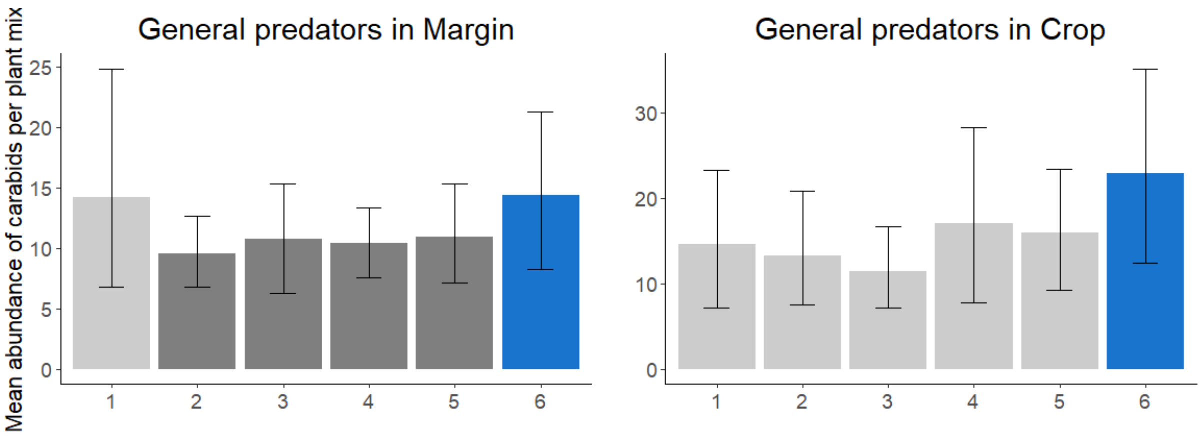


Figure 2. Differences in mean abundances +/- SE of general predators between mixes in the margin and the adjacent crop. Significantly higher abundances in blue ($p < 0.001$), lower in dark grey ($p < 0.001$), no change in light grey.

Discussion

The use of different plant mixes caused no discernible increase or decrease in abundance over cropping to the field edge. The higher diversity indices in the combined margin, suggest an edge effect as no individual mix was better than the cereal control. These plots may have a local effect on the whole area as carabid beetles are mobile, and a comparison with unmargined fields would provide more insight into this.

Studies in Britain and Germany found carabid richness in crops was lower in the presence of an arable margin which was suggested to be a sink effect of the margin attracting carabids away from the crop (Fusser et al., 2018; Jowett et al., 2019). In contrast, this study found that richness was higher in the cereal areas (the tramline samples and the cereal control plot) than the grassy plots of the margin. The lower species richness in the grass plots compared to the cereal areas does not support a sink effect of the margin. It is likely that the crop was more attractive and accessible for mobile beetles as with Allema et al. (2019), where *Pterostichus melanarius* beetles were more mobile in cereal areas than dense grasses in a field margin. However, sampling efficiency could also have been negatively affected by the dense margin vegetation.

A mix ideal for pest control (i. e. that increases the abundance of carabids) was not apparent in this study and no spillover effects in the adjacent crop were seen. This may have been an effect of the time of year these samples were taken, and spillover might be evident later in the season. Arable margins may have more value as a refuge in conventional agriculture where insecticides are used regularly and there may be evident differences in abundance, richness and diversity in these local environments (Plantegenest et al., 2019).

There is merit to further investigate pest control using broad taxonomic groups mediated by differing margin mixes to adjacent fields (using general predators and pest specific predators). If predator populations are increased whether this translates to a discernible effect to the adjoining crop health and pest abundance is also worth examining. Surveying for overwintering carabid species might also give a better understanding of which species move from the margin to the crop or vice versa in spring/summer.

References

Allema, B., Hemerik, L., Rossing, W. A., Groot, J. C., van Lenteren, J. C. and van der Werf, W. 2019: Dispersal of a carabid beetle in farmland is driven by habitat-specific motility and preference at habitat interfaces. Entomol. Exp. Appl, 167: 741-754.

Anderson, M. J., Walsh, D. C. I., Robert Clarke, K., Gorley, R. N. and Guerra-Castro, E. 2017: Some solutions to the multivariate Behrens – Fisher problem for dissimilarity-based analyses. Aust. N. Z. J. Stat. 59: 57-79.

Cole, L. J., McCracken, D. I., Dennis, P., Downie, I. S., Griffin, A. L., Foster, G. N., Murphy, K. J. and Waterhouse, T. 2002: Relationships between agricultural management and ecological groups of ground beetles (Coleoptera: Carabidae) on Scottish farmland. Agriculture, Ecosystems and Environment 93(1-3): 323-336.

Fusser, M. S., Holland, J. M., Jeanneret, P., Pfister, S. C., Entling, M. H. and Schirmel, J. 2018: Interactive effects of local and landscape factors on farmland carabids. Agr. Forest Entomol. 20: 549-557.

Ganser, D., Knop, E., and Albrecht, M. 2019: Sown wildflower strips as overwintering habitat for arthropods: Effective measure or ecological trap? Agriculture, Ecosystems and Environment 275: 123-131.

Habitas.org.uk 2006: Ground Beetles of Ireland: Habitats. National Museums Northern Ireland. http://www.habitas.org.uk/groundbeetles/fauna.html. Accessed 4 May 2022.

Hartig, F. 2020: DHARMa: residual diagnostics for hierarchical (multi-level/mixed) regression models. R package version 0.3, 3.

Jones, D. L. 2014: The Fathom Toolbox for Matlab: multivariate ecological and oceanographic data analysis. College of Marine Science, University of South Florida, St. Petersburg, Florida.

Jowett, K., Milne, A. E., Metcalfe, H., Hassall, K. L., Potts, S. G., Senapathi, D., and Storkey, J. 2019: Species matter when considering landscape effects on carabid distributions, Agriculture, Ecosystems and Environment 285: 106631.
Luff, M. L. 2007: The Carabidae of Britain and Ireland. Royal Entomological Society.
Magnusson, A., Skaug, H., Nielsen, A., Berg, C., Kristensen, K., Maechler, M., van Bentham, K., Bolker, B., Brooks, M. and Brooks, M. M. 2017: Package'glmmtmb'.R Package Version0.2.0.
Oksanen, J., Blanchet, F. G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P. R., O'Hara, R. B., Simpson, G. L., Solymos, P. and Stevens, M. H. H.2021: vegan: Community Ecology Package. R package version 2.5-7. 2020.
Plantegenest, M., Aviron, S., and Pétillon, J. 2019: Local vs. landscape characteristics differentially shape emerging and circulating assemblages of carabid beetles in agroecosystems. Agriculture, Ecosystems and Environment 270: 149-158.
Sunderland, K. D. 2002: Invertebrate pest control by carabids. In: The agroecology of carabid beetles (ed. Holland, J. M.): 165-214. Intercept, Andover.
Trichard, A., Ricci, B., Ducourtieux, C., and Petit, S. 2014: The spatio-temporal distribution of weed seed predation differs between conservation agriculture and conventional tillage. Agriculture, Ecosystems and Environment 188: 40-47.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 77-81

Landscape effects on the cabbage seedpod weevil, *Ceutorhynchus obstrictus*, on canola in Quebec (Canada)

Marie D'Ottavio[1], Sébastien Boquel[2], Geneviève Labrie[3], Éric Lucas[1]
[1]UQAM, Laboratoire de lutte biologique, Université du Québec à Montréal, Département des sciences biologiques, Case Postale 8888, Succursale Centre-Ville, Montréal (Qc), Canada, H3C 3P8; [2]CEROM, 740, chemin Trudeau, Saint-Mathieu-de-Beloeil (Qc), Canada, J3G 0E2; [3]CRAM, 9850, rue Belle-Rivière, Mirabel (Qc), Canada, J7N 2X8

Abstract: The exotic pest *Ceutorhynchus obstrictus* accidentally introduced in 1931 in North America is one of the main pests of canola crops. The objective of the present study is to evaluate the influence of landscape predictors on *C. obstrictus* infestation in Quebec. Fieldwork has been conducted in 140 canola fields across eight Quebec regions from 2015 to 2020. Results show that pest infestation increases when proportions of roads and cereals are higher in the landscapes surrounding canola crops.

Key words: pest, agroecosystem, spatial context, Nearctic landscape, road, cereal

Introduction

In 1931, *Ceutorhynchus obstrictus* (Marsham) (Coleoptera: Curculionidae) was accidentally introduced in North America (Vancouver) (McLeod, 1962) and then has spread all over this continent. It was found in South Quebec in 2000 and in Ontario in 2001 (Brodeur et al., 2001). Mating occurs during canola blooming and females feed on buds, flowers and pods before laying eggs in pods. Worst damage is caused by larvae when feeding on oilseed rape pod seeds, before emerging from siliquae and pupate in the soil (Bonnemaison, 1957).

To date, there is a single study that clearly analysed landscape predictor effects on *C. obstrictus* in European landscapes (Estonia) (Kovács et al., 2019). The infestation rate of *C. obstrictus* resulted higher in the presence of abandoned fields, hayfields, wheat crops and permanent grasslands. Herbaceous linear habitats bordering oilseed rape crops also had a positive effect on the infestation rate. Moreover, infestation rate was higher when adjacent habitats of oilseed rape crops were herbaceous linear rather than hedgerows or other crops. However, Kovács et al. (2016) found no significant effect of the bordering habitat of the oilseed rape crop on infestation rate.

The objective of the present study is to evaluate the influence of landscape predictors on *C. obstrictus* infestation in Nearctic landscapes of Quebec. It was hypothesized that the higher the proportions of canola crops, hay/pastures and forests in the landscape, the higher the infestation rate in canola crop. In fact, landscape dominated by the host crop provides high resource concentration and the pest has a higher probability to find it (e. g. Maisonhaute et al., 2017). Also, in the presence of hayfields surrounding canola crops, *C. obstrictus* infestation rate is higher (Kovács et al., 2019). Finally, this weevil overwinters under soil or litter of woodlands (e. g. Veromann et al., 2010) and more *Ceutorhynchus erysimi* were found in oilseed rape crops near a forest (Berger et al., 2018).

Materials and methods

Sampling

Sampling was done in 140 canola fields between 2015 and 2020. Depending on the year, sampling was done in five to seven Quebec regions with a total of eight regions: Montérégie, Estrie, Centre-du-Québec, Chaudière-Appalaches, Capitale-Nationale, Bas-Saint-Laurent, Saguenay-Lac-Saint-Jean and Abitibi-Témiscamingue (from 47°25'44.4"N, 79°27'42.1"W to 48°24'14.5"N, 67°24'09.9"W). In each canola field, 1,000 siliquae were collected in August, near canola field edges, when their final size was reached, totalizing 140,000 siliquae across all the experimental period.

Emergence boxes

Pods from a single field were placed in an emergence box (30 × 30 × 30 cm). About four weeks later, boxes were opened and emergence holes (of *C. obstrictus* and/or of parasitoids) on pods and emerged larvae were counted. Each pod was carefully inspected using a binocular magnifier (LEICA MZ6, Wetzlar, Germany). Infestation rate by *C. obstrictus* was calculated for each canola field. All pods and emergence holes were considered for the calculation.

Landscape predictors measures

Landscape predictors measures were done with ArcGIS software 10.6 (ESRI, 2017) and based on two shapefiles: one for the crops (Financière Agricole du Québec, Gouvernement du Québec) and one for all landscape categories (Utilisation du territoire, Gouvernement du Québec). Hedgerows lengths were based on the ArcGIS basemap World Imagery. Measures were centered from each sampled canola field by considering a 1 km diameter around. A total of 21 landscape predictors were included in the analyses.

Statistical analyses

All statistical analyses were performed with R software (V. 3.6.1; R Core Team, 2020) using the "lme4", "car" and "MASS" packages. A correlation matrix allowed to check for potential correlations between landscape variables. A correlation threshold of 75 % (Spearman coefficient) was considered. Linear Mixed Model (LMM) were used with an arcsine-square-root transformation. Region and year were included in models as crossed random effects. A stepwise regression was used by adding or dropping independent variables, one at a time. A weight parameter was added in models. Potential multicollinearities were checked between independent variables with the Variance Inflation Factor (VIF) function. The best model was chosen according to the lowest second-order Akaike Information Criterion (AICc).

Results and discussion

Our hypothesis of the effect of higher proportions of canola crops, hay/pastures and forests was not validated in our landscapes. However, two predictors had a significant effect (p-value < 0.05) on *C. obstrictus* infestation rate. When more roads and cereal crops were present in the landscape, a higher *C. obstrictus* infestation rate was observed in canola crops (Table 1). Mean proportions of cereal species per landscape for all years were mostly represented by wheat (34.75 %) and barley (35.63 %) crops. Oat crops come third (25.55 %) in the different landscapes (Figure 1).

Table 1. Final model representing effects of landscape predictors on *C. obstrictus* infestation rate. The dependent variable was arcsine-square-root transformed.

Predictors	Estimates	df	t-value	CI	p-value
Intercept	0.09	11.41	1.69	[- 0.01, 0.19]	0.091
% of roads	**1.20**	125.62	3.69	[0.56, 1.84]	< **0.001**
% of cereals	**0.14**	126.98	2.05	[0.01, 0.28]	**0.041**

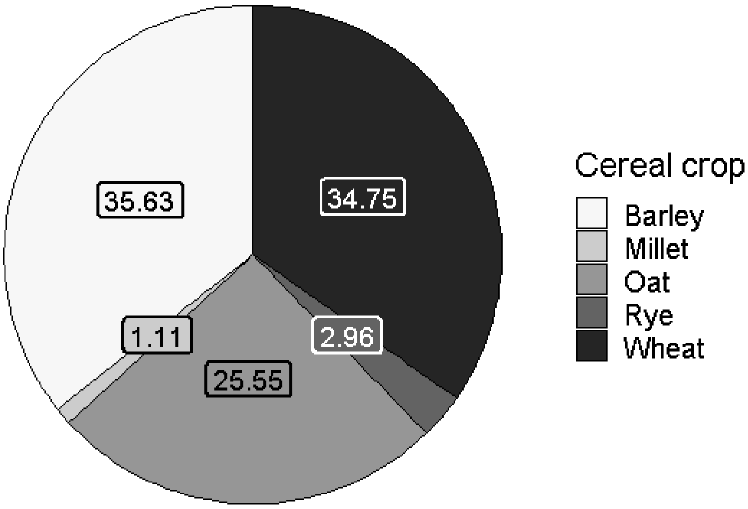


Figure 1. Mean proportion (%) of cereal crops per landscape for all years.

Almost a third of landscapes (31.43 %) contains roads in our study. These are open spaces which probably not act as barriers for continuous flight of *C. obstrictus*, in contrast to small and flightless insects (Muñoz et al., 2015). In fact, *C. obstrictus* is an active flier able to travel several kilometers in one season. Its flight is relatively high, more than 3 m high at 25 °C, and it lets itself be carried out by wind turbulence and convection movements at great altitudes (Tansey et al., 2010). It could thus be able to avoid vehicles at low and high-traffic levels and benefit from open spaces of roads to reach canola fields. Moreover, many road edges contain floral resources and *C. obstrictus* could feed on cruciferous weeds present in these edges. A recent study found that *C. obstrictus* feeds on some cruciferous species present in edges (Desroches et al., in prep.). Furthermore, road edges are overwintering sites for Curculionidae (Schaffers et al., 2012), contributing to explain the higher infestation rate observed in this study.

In our 140 different typologies of landscapes, 93 presented at least one cereal crop, and 40 (43.01 %) presented at least one cereal crop in rotation with a canola crop. Thus, canola crop is regularly followed by a cereal crop in rotation (Zoghlami et al., 2013), especially barley and wheat (Figure 1). The next generation of *C. obstrictus* emerging in the canola field in August seeks for floral resources near the field, before overwintering in the area (Dosdall et al., 2001). Next Spring, this overwintering generation emerges and is therefore already present in the landscape where the canola field is now a cereal field. Volunteer canola could also be present in the cereal crop, allowing some *C. obstrictus* individuals to stay, feed and lay eggs in pods. Whaley et al. (2016) found that volunteer winter canola in winter wheat can often be a host to

C. obstrictus in Douglas County (Washington). Kovács et al. (2019) also found that wheat had a positive effect on *C. obstrictus* infestation rate in oilseed rape crops in Estonia.

Further studies are needed to evaluate the landscape effects on key parasitoids of *C. obstrictus* in North America, in order to determine the biocontrol potential of this pest in our landscapes.

Acknowledgements

We thank the Canola Council of Canada for financing the project, the Financière Agricole du Québec and the Government of Québec for spatial data. We also thank all farmers involved, the Laboratoire de lutte biologique for collecting some data, Mélanie Desrochers for helping in ArcGIS analyses and Jill Vandermeerschen for helping in statistical analyses.

References

Berger, J. S., Birkhofer, K., Hanson, H. I., and Hedlund, K. 2018: Landscape configuration affects herbivore-parasitoid communities in oilseed rape. Journal of pest science 91(3): 1093-1105.

Bonnemaison, L. 1957: Le charançon des siliques (*Ceutorhynchus assimilis* Payk.) Biologie et Méthodes de lutte. Annales de l'institut national de la recherche agronomique - Serie C: Annales des Epiphytes 8 (IV): 387-542.

Brodeur, J., Leclerc, L. A., Fournier, M., and Roy, M. 2001: Cabbage seedpod weevil (Coleoptera: Curculionidae): new pest of canola in northeastern North America. The Canadian Entomologist 133(5): 709-711.

Dosdall, L. M., Moisey, D., Cárcamo, H., and Dunn, R. 2001: Cabbage seedpod weevil factsheet. Agdex 622-21, Alberta Agriculture. Food and Rural Development, Edmonton, Alberta.

Kovács, G., Kaasik, R., Treier, K., Luik, A. and Veromann, E. 2016: Do different field bordering elements affect cabbage seed weevil damage and its parasitism rate differently in winter oilseed rape? IOBC-WPRS Bull. 116:75-80.

Kovács, G., Kaasik, R., Lof, M. E., van der Werf, W., Kaart, T., Holland, J. M., and Veromann, E. 2019: Effects of land use on infestation and parasitism rates of cabbage seed weevil in oilseed rape. Pest management science 75(3): 658-666.

Maisonhaute, J. E., Labrie, G., and Lucas, E. 2017: Direct and indirect effects of the spatial context on the natural biocontrol of an invasive crop pest. Biological Control 106: 64-76.

McLeod, J. H. 1962: Cabbage seedpod weevil – *Ceutorhynchus assimilis* (Payk.) Curculionidae. A review of the biological control attempts against insects and weeds in Canada. Farnham Royal, Bucks: Commonwealth Agricultural Bureaux (CAB): 5-6.

Muñoz, P. T., Torres, F. P., and Megías, A. G. 2015: Effects of roads on insects: a review. Biodiversity and Conservation 24(3): 659-682.

Schaffers, A. P., Raemakers, I. P., and Sýkora, K. V. 2012: Successful overwintering of arthropods in roadside verges. Journal of Insect Conservation 16(4): 511-522.

Tansey, J. A., Dosdall, L. M., Keddie, A., and Olfert, O. 2010: Flight activity and dispersal of the cabbage seedpod weevil (Coleoptera: Curculionidae) are related to atmospheric conditions. Environmental Entomology 39(4): 1092-1100.

Veromann, E., Williams, I. H., Kaasik, R., and Luik, A. 2010: Potential of parasitoids to control populations of the weevil *Ceutorhynchus obstrictus* (Marsham) on winter oilseed rape. International Journal of Pest Management 57(1): 85-92.

Whaley, D. K., Young, F. L., Sowers, K., and Roe, D. 2016: Cabbage Seedpod Weevil Management in Canola. Washington State University Extension: 5.

Zoghlami, S., Bergeron, M., Moore, H., Labrie, G., Pageau, D., Robert, L., Tardif, É., and Tremblay, G. 2013: Guide de Production du Canola. Fédération des Producteurs de Cultures Commerciales du Québec: 2.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 82-85

Selection of ornamental species with different degrees of shade tolerance in urban green spaces

Alessandra Francini[1], Stefania Toscano[2], Antonio Ferrante[3], Ilda Vagge[3], Daniela Romano[2]
[1]Scuola Superiore Sant'Anna Pisa, Piazza Martiri della libertà 33, Pisa, Italy; [2]Università degli Studi di Catania, Dipartimento di Agricoltura, Alimentazione e Ambiente, Via Valdisavoia 5, 95123 Catania, Italy; [3]Università degli Studi di Milano, Dipartimento di Scienze Agrarie e Ambientali, Via Celoria 2, 20133 Milano, Italy
E-Mail: antonio.ferrante@unimi.it

Abstract: The ornamental green of urban areas is determined by the choice of the species and their combination or integration with pre-existing plants. The herbaceous and shrub species must be positioned so that the availability of light is sufficient to ensure the satisfaction of the basal metabolism throughout the vegetation period which includes the different seasons. Ornamental species, according to shade tolerance or the need for good irradiance, are classified into shade and sun plants. To properly position the plants, especially when in the immediate vicinity of buildings, it is necessary to study the projection of shadows during the year and in particular in the most critical periods such as July and August. As with light, shadow can also be classified and for simplicity, three levels of shading can be identified:

- light or bright shade: the area of interest can be completely shaded for a few hours a day, every day. The sun's rays are blocked for several hours a day by a building or a wall, but the rest of the day the area is sunny.
- partial or partial shade: the area is shaded for most of the day, but in the early morning or in the evening the plants are reached by the sun's rays.
- complete or total: the area is shaded all day.

The position of species with different degrees of shade tolerance can be obtained by the determination of the light compensation point for each species, that is, the minimum amount of light that allows equating the assimilation of carbon dioxide with photosynthesis to the carbon dioxide emitted by respiration. This state of biological stalemate for the plant represents the most critical condition that the plant itself can endure during the critical summer period. The distribution of the species within an area should follow the minimum light intensity that guarantees to compensate for respiration such that net photosynthesis is greater than zero in a 24hr period. In this context, this study classifies, on an objective basis, the most common ornamental species used in the Mediterranean environment based on light requirements.

Key words: compensation point, shadow projection, shade plants, sun plants

Introduction

The selection of plants when planning green urban and peri-urban areas is carried out considering the ornamental value and the ability to adapt to different conditions with annual, perennial, and woody shrub species selected considering their tolerance to biotic and abiotic stresses (Toscano et al., 2019). Light is of primary importance for photosyntheiss and plant morphology (Cocetta et al., 2017), and the lack of light can reduce growth and affect ornamental quality. In line with this, the combination and integration of plants must consider shading by buildings or other plants in the area. In simple terms, ornamental species can be classified into shade and sun plants according to shade tolerance or the need for good irradiance. Shadow can be also classified and for simplicity, three levels of shading or light intensity can be identified:

- light or bright shade: the area of interest can be completely shaded for a few hours a day, every day. The sun's rays are blocked form buildings or vegetation for several hours in a day, but the rest of the day the area is in full sun exposure;
- partial or partial shade: the area is shaded for most of the day, but in the early morning or in the evening the plants are reached by the sun's rays;
- complete or total shade: the area is shaded all day.

These provide a general guide for the selection and positioning of ornamental plants within a proposed green area but a more detailed consideration of light requirements would be beneficial.

Physiological and environmental parameters

Light or shading intensity and temperature have direct effects on photosynthesis and respiration, therefore, the changes of these physiological processes in response to light intensity reduction and temperature increase must be studied. The minumum light intensity at which photosynthesis compensates for respiration sets the adequate light compensation point for ornamental plants used in the urban and peri-urban green areas. With this in mind, shade projections, i. e. the patterns of light intensity resulting from the shading of buildings and other objects must be identified all year around, although most importantly during spring and summer. Furthermore temperature must also be accounted for as net photosynthesis is temperature dependent, increasing temperature enhances the respiration rate and reduces the net photosynthesis. As a result, in the hottest weeks of summer, plants that have a high light compensation point may produce insufficient carbohydrates for storage or growth leading to plant death.

Ornamental plant selection and placement

Photosynthesis and respiration of ornamental plants

As established above, ornamental plants used in the urban and peri-urban green spaces must be adapted to the prevailing shade or light conditions. As a general guide shade tolerant plants should be used in shaded areas and sun plants in areas of full sun light. However, shade is not constant throughout the day or during different months. Therefore, it is important to identify the shade intensity of trees or buildings around the area where the green area will be created. The correct selection of plants in the area should be carried out matching the light compensation point of each species with the light intensity and photoperiod throughout the daily and seasonal cycles. For example, Figure 1 illustrates how to distribute the plants with different light compensation point values.

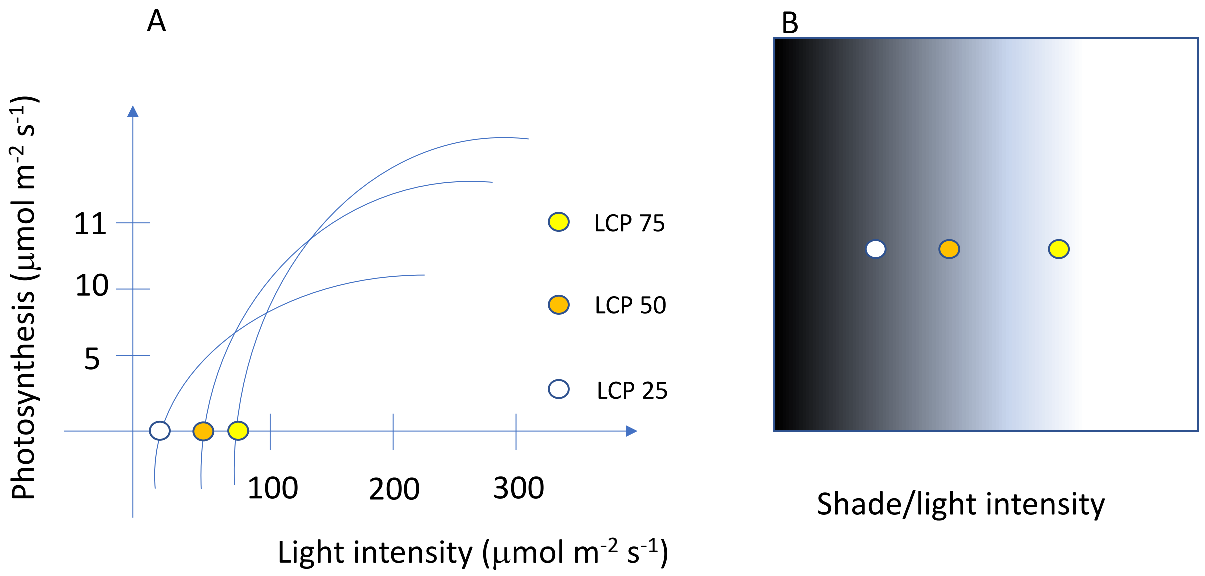


Figure 1. Light saturation curves and light compensation points (LCP) of three different ornamental species (A) and the positioning of plants in different shade or light intensity that match with the requirement of LCP in the 24 h basis (B).

In summer, the more extensive plant canopies and the higher temperature can reduce the photosynthesis activity and increase the respiration resulting in negative net photosynthesis. Therefore, the selection of plants should account for this ensuring that the amount of light is sufficient for the compensation of the respiration rate in a 24 h interval. The problem is less acute in spring as typically plants do not show symptoms of shading, although with the arising of temperature the plants start to suffer of limited light conditions.

Adaptation to light conditions

As reported in the Table 1, ornamental plants may have low or high light compensation points. However, plants can change the light compensation points, adapting to different environments. For example, *Plectranthus scutellarioides* showed an increase of light compensation points in plants grown under HPS and red LED (Domurath et al., 2012). Lower compensation points can also be found in plants adapted to indoor conditions such as *Philodendron erubescens* or *Dracaena surculose* (Tan et al., 2017), while an analogous experiment simulating indoor conditions by lowering light intensity resulted in reduced light compensation points in *Leea coccinia* and *L. rubra* (Sarracino et al., 1992). Different light compensation points can also be observed on the same plant under different light exposure conditions (Zhao et al., 2012). Leaves of *Peonia lactiflora* exposed to the sun showed double the light compensation point when compared to those under shade. This information can be useful when selecting plants for use in shaded locations as adaptation may be used to lower the light composition point of a species at the nursery level by applying different shading nets.

Table 1. Light compensation points of different species and light intensity in the area during the day of the most critical season.

Species	**Light compensation point ($\mu mol/m^2$ s)**	**Shade/light range 24 h ($\mu mol/m^2$ s)**	**Reference**
Philodendron erubescens or *Dracaena surculosa*	6-12	> 15	Tan et al., 2017
Peonia lactiflora	7-13	> 15	Zhao et al., 2012
Plectranthus scutellarioides	15	> 20	Domurath et al., 2012
Pelargonium grandiflorum	27	> 30	
Leea coccinea	52-88	> 90	Sarracino et al., 1992
Leea rubra	67-84	> 90	Sarracino et al., 1992

Acknowledgements

The activities are part of the Master's course in "Progettazione delle aree verdi e del paesaggio" involving the Universities of Milano, Genova, Turin.

References

Cocetta, G., Casciani, D., Bulgari, R., Musante, F., Kołton, A., Rossi, M., and Ferrante, A. 2017: Light use efficiency for vegetables production in protected and indoor environments. The European Physical Journal Plus 132(1): 1-15.

Burnside, C. A., and Böhning, R. H. 1957: The effect of prolonged shading on the light saturation curves of apparent photosynthesis in sun plants. Plant Physiology 32(1): 61.

Domurath, N., Schroeder, F. G., and Glatzel, S. 2012: Light response curves of selected plants under different light conditions. Acta Hort. 956: 291-298.

Sarracino, J. M., Merritt, R., and Chin, C. K. 1992: Light acclimatization potential of *Leea coccinia* and *Leea rubra* grown under low light flux. HortScience 27(5): 404-406.

Tan, C. L., Wong, N. H., Tan, P. Y., Ismail, M., and Wee, L. Y. 2017: Growth light provision for indoor greenery: A case study. Energy and Buildings 144: 207-217.

Toscano, S.; Ferrante, A.; Romano, D. 2019: Response of Mediterranean ornamental plants to drought stress. Horticulturae 5: 6.

Zhao, D., Hao, Z., and Tao, J. 2012: Effects of shade on plant growth and flower quality in the herbaceous peony (*Paeonia lactiflora* Pall.). Plant physiology and biochemistry 61: 187-196.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 86-91

Site-specific weed management based on species-specific weed densities

Mona Schatke*, Christoph von Redwitz, Arnd Verschwele, Heidrun Bückmann, Christoph Kämpfer, Lena Ulber
Julius Kühn Institute (JKI) – Federal Research Centre for Cultivated Plants, Institute for Plant Protection in Field Crops and Grassland, Brunswick, Germany
*E-Mail: *mona.schatke@julius-kuehn.de*

Abstract: Blanket in-crop herbicide application over the entire field is, due to the heterogeneous distribution of weeds, in most cases both environmentally unfavourable and economically unprofitable. Novel technologies such as automatic weed recognition enable the determination of weed distribution with high spatial resolution and form the necessary basis for site-specific herbicide applications.

The present study proposes a weed management approach that aims to create spatially explicit management plans based on decisions taken at the weed species level. To obtain site-specific information, species-specific weed distribution and density across the field must be first determined. Weed distribution maps are subsequently generated with a geoinformation system (GIS) for the weed species most commonly found on the field. Economic thresholds indicate the weed density at which herbicide application is economically justified and therefore provide valuable decision support for weed control decisions. In this study, existing thresholds for prevalent weed species are used as a basis for developing management plans. A site-specific herbicide application map is developed and used to determine the type of herbicide required to control each species according to its economic threshold. Site-specific management plans based on each species' economic threshold are a necessary step in reducing herbicide use and increasing weed diversity on cropland.

Key words: site-specific weed control, weed detection, precision farming, species-specific

Introduction

In situations of high weed densities, weed control is usually required to reduce weed competition. Up to now, weed control is mostly conducted by using herbicides, which may enter adjacent ecosystems through processes such as drift, evaporation or deposition and have been associated with a decline in biodiversity. However, an increased weed diversity may have positive impacts on the functioning of agro-ecosystems (Franke et al., 2009) by supporting beneficial ecological services such as pollination (Gabriel and Tscharntke, 2007) and provision of habitat, feeding and reproduction sites for natural enemies of pests (Nentwig et al., 1998). Individual weed species are known to differ in their ecological function as well as in their impediment to crop production (Storkey and Westbury, 2007). Innovative weed control strategies such as site-specific weed management (SSWM) have therefore been developed and offer a promising potential to deliver a more productive and sustainable agricultural production based on a more precise and therefore biodiversity-friendly usage of herbicides (Fernández-

Quintanilla et al., 2018). The concept of SSWM, in simplified form, consists of three key elements:

1. Identification and location of the weed distribution across the field.
2. Development of a management concept based on the monitored weed distribution. Decisions can be made based on the simple presence (or absence) of weeds, or by distinguishing between the type or species of weeds that occur.
3. Site-specific herbicide application. Till now, only a few precise and site-specific spraying technologies are in use in commercial agriculture, although the theorie has shown a significant development and potential (Christensen et al., 2009).

Here, we present a workflow for preparing SSWM plans. In addition, different herbicide application strategies based on the species-specific weed occurrence on a area are compared regarding their potential to reduce herbicide inputs and to increase weed diversity.

Materials and methods

Weed detection

The field trials were carried out in cooperation with an external farmer close to Brunswick. An area of approximately 2840 m^2 of a winter wheat field was used for the study. In the beginning of the study, a sampling grid of 40 grid points was installed on the study area. Grid size was 24 × 100 m and grid sampling points were installed at each grid intersection. No herbicide treatment was applied to the study area in spring and autumn. The presence of weeds was assessed on 28.02.2022 by manually determining the number of individual weed plants in a plot of 0.1 m^2 at each grid point.

Weed distribution map

Based on the recorded weed occurence at the individual grid points, a weed distribution map was created using an interpolation approach. We used the inverse distance interpolation method, generated with a geo-information system (GIS).

Management plan

Based on the generated weed distribution map, we applied four different weed management scenarios and compared the size of the potentially herbicide-untreated area.

Scenario 1: Herbicide application over the entire study area, without considering the spatial distribution of weeds;

Scenario 2: Herbicide application only to those parts of the study area where weeds were present;

Scenario 3: Herbicide application based on economic thresholds for mono-, dicotyledonous weeds and *Galium aparine*;

Scenario 4: Herbicide application based on thresholds for individual weed species.

Threshold values for mono- and dicotyledonous weeds (Scenario 3) are based on economic thresholds recommended for practical use in cereals (Gerowitt and Heitefuss, 1990). The economic threshold is 20 plants per m^2 for monocotyledonous weeds, 40 plants per m^2 for dicotyledonous weeds and 0.1 plants m^2 for *G. aparine*. For the individual weed species (Scenario 4), control thresholds are used (Bayrische Landesanstalt für Landwirtschaft, 2022).

The observed weeds with the corresponding thresholds (in plants per m^2) are *G. aparine* L. (0.1), *Viola arvensis* Murray (5), *Stellaria media* (L.) Vill. (25), *Alopecurus myosuroides* Huds. (15) and *Matricaria spp*. (3). If the level of weed infestation exceeds these defined thresholds and no weed control measures are applied, economic losses are to be expected. If the threshold for one species is exceeded, the area is classified as requiring treatment.

Results

Weed distribution

First, weed distribution maps were created based on the weed sampling data (Figure 1). The highest weed density was found for *V. arvensis* (up to 120 plants per m^2). A maximum of four plants per m^2 was detected for *G. aparine*. For the remaining weed species, not more than two plants per m^2 were counted at any grid point.

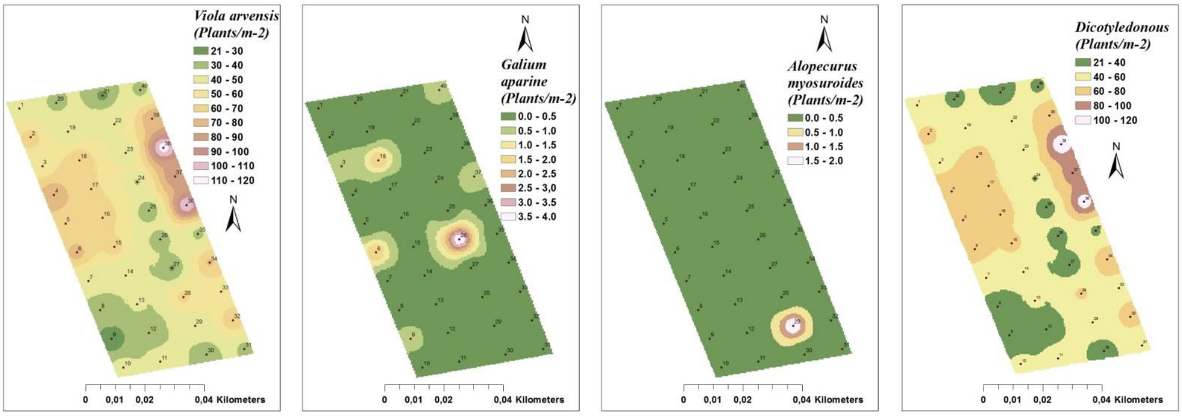


Figure 1. Weed distribution maps for weed species present at the study area. The map for “Dicotyledonous” includes *Viola arvensis*, *Stellaria media*, *Matricaria spp*. and excludes *G. aparine*.

Weed control

In consultation with the cooperating farmer, we hypothetically chose an herbicide product based on the present weed species that required control. In Scenario 1, the whole area (2840 m^2) would have been treated, which was regarded as an herbicide input of 100 %. Using this scenario as a reference, potential herbicide savings in the other three scenarios were calculated. Since we found weeds at each grid point, the entire area would have to be treated under Scenario 2 and no herbicide savings were feasible.

Different results were obtained when thresholds for mono- and dicotyledonous weeds as well as *G. aparine* were used in Scenario 3. In this case, only *A. myosuroides* was present as a monocotyledonous species and its densities did not exceed the threshold value on the entire study area. The densities of the dicotyledonous species exceeded the thresholds at 28 grid points. The results of Scenario 3 showed that 7.19 % (resp. 204.16 m^2) of the area did not require herbicide treatment (Figure 2).

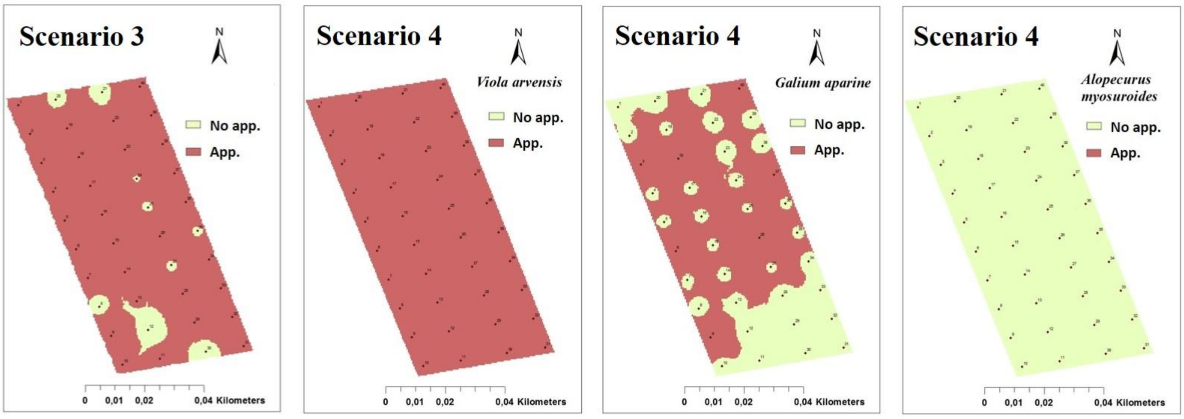


Figure 2. Management-maps based on Scenario 3 and 4. A distinction is made between the area to be treated (App.) and the area not to be treated (No app.).

The threshold values for the individual weed species observed in the experimental area (Scenario 4) were lower than those for the mono- and dicotyledonous classification. Densities of *V. arvensis* exceeded the threshold value over the entire area, so that an herbicide treatment over the entire area would have been required. If we consider *G. aparine* only and ignore the high weed densities of *V. arvensis*, the combination of SSWM and economical thresholds would have left 34.01 % (resp. 966 m^2) of the area untreated. The other weed species detected (*Matricaria* spp., *S. media* and *A. myosuroides*) did not exceed the threshold and did not require treatment.

Discussion

In order to make SSWM more practical and attractive for farmers, cost- and time-efficient tools for mapping of weed distribution in the field need to be developed. Improved detection and management approaches that take into account weed species identity, population density, stage of development and potential economic impact on crop yields may be a possible approach to apply herbicides in a more targeted manner (Liebman et al., 2016).

Because *V. arvensis* exceeded the species-specific economic threshold at all grid points, herbicide savings did not occur in scenarios 1, 2, and 4. Only SSWM with classification into mono- and dicotyledonous weeds resulted in an untreated area of about 7.2 %. In addition to herbicide savings, leaving parts of the areas untreated would allow certain weed species to persist and sustain higher trophic levels. *V. arvensis,* for example, has a high importance for seed eating birds but does not provide food or habitat for crop pest species (Marshall et al., 2003). Blanking out the most common species *V. arvensis*, SSWM based on species-specific thresholds saved the most herbicides (about 34 % of the area untreated). The observed species *S. media*, *G. aparine* and *A. myosuroides* are omitted from herbicide treatment under Scenario 4 because they do not exceed species-specific thresholds. This may have a significant long-term impact on biodiversity due to their ecosystem services: *S. media* and *Matricaria recutita* support seed eating birds (Marshall et al., 2003). For invertebrates, species like *S. media, M. recutita* and *G. aparine* are important. These species also provides food or habitat for crop pest species (Marshall et al., 2003). Appropriate adaptation of management to these needs can ensure that relevant weeds are maintained in crops for support of birds and insects.

The difference between the results with the species-specific discrimination or the classification into mono- and dicotyledonous weeds showed that the value of the threshold has a strong impact on the outcome and potential of the SSWM. Currently, threshold values that accurately represent both the crop-competition potential of a weed species and the ecological services it can provide are lacking. The biological and ecological functions and traits of each weed species should be further investigated and considered in setting thresholds for management decisions. Influencing factors such as herbicide costs, yield potential and management have changed since the estimation of thresholds in the 80s and 90s. For the development of site- and species-specific weed management concepts, a provision of maps is not sufficient (Coleman et al., 2019). What is needed is a controlled use of SSWM to verify that the technique achieves the goals of modern techniques for identification and in the final step, the management results.

References

Bayrische Landesanstalt für Landwirtschaft 2022: Leitunkräuter im Getreide. Integrierter Pflanzenschutz URL https://www.lfl.bayern.de/ips/unkraut/131212/index.php. Accessed 21 Apr. 2022.

Christensen, S., Søgaard, H. T., Kuds, P., Nørremark, M., Lund, I., Nadimi, E. S. and Jørgensen, R. 2009: Site-specific weed control technologies. Weed Research 49(3): 233-241. doi: 10.1111/j.1365-3180.2009.00696.x.

Coleman, G. R. Y., Stead, A., Rigter, M. P., Xu, Z., Johnson, D., Brooker, G. M. et al. 2019: Using energy requirements to compare the suitability of alternative methods for broadcast and site-specific weed control. Weed Technology 33(4): 633-650. doi: 10.1017/wet.2019.32.

Fernández-Quintanilla, C., Peña, J. M., Andújar, D., Dorado, J., Ribeiro, A. and López-Granados, F. 2018: Is the current state of the art of weed monitoring suitable for site-specific weed management in arable crops? Weed Research 58(4): 259-272. doi: 10.1111/wre.12307.

Franke, A. C., Lotz, L. A. P., van der Burg, W. J. and van Overbeek, L. 2009: The role of arable weed seeds for agroecosystem functioning. Weed Research 49(2): 131-141. doi: 10.1111/j.1365-3180.2009.00692.x.

Gabriel, D. and Tscharntke, T. 2007: Insect pollinated plants benefit from organic farming. Agriculture, Ecosystems & Environment 118(1-4): 43-48. doi: 10.1016/j.agee.2006.04.005.

Gerowitt, B. and Heitefuss, R. 1990: Weed economic thresholds in cereals in the Federal Republic of Germany. Crop Protection 9(5): 323-331. doi: 10.1016/0261-2194(90)90001-N.

Liebman, M., Baraibar, B., Buckley, Y., Childs, D., Christensen, S., Cousens, R. et al. 2016: Ecologically sustainable weed management: How do we get from proof-of-concept to adoption? Ecological Applications 26(5): 1352-1369.

Marshall, E. J. P., Brown, V. K., Boatman, N. D., Lutman, P. J. W., Squire, G. R. and Ward, L. K. 2003: The role of weeds in supporting biological diversity within crop fields. Weed Research 43(2): 77-89. doi: 10.1046/j.1365-3180.2003.00326.x.

Nentwig, W., Frank, T. and Lethmayer, C. 1998: Sown weed strips. In: Conservation Biological Control. Elsevier: 133-153.

Storkey, J. and Westbury, D. B. 2007: Managing arable weeds for biodiversity. Pest Management Science 63(6): 517-523. doi: 10.1002/ps.1375.

Funding

The project is supported by funds of the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the Parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE) under the innovation support programme.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 92-96

Field margin measures from a farmers' perspective

Friederike de Mol, Merle Hamacher, Bärbel Gerowitt
University of Rostock, Agricultural and Environmental Sciences, Crop Health, Satower Str. 48, 18051 Rostock, Germany
E-Mail: friederike.de-mol@uni-rostock.de

Abstract: Field margins can provide benefits for ecosystems in intensive arable areas. They are a part of agri-environmental programs aimed at preserving or restoring habitats for specific animals and plants, or for increasing biodiversity in general. Despite these advantages, intensive agricultural regions have the lowest share of implemented agri-environmental programs. The key to achieving biodiversity goals is to increase the participation of farmers in these programs. In order to analyse the factors favouring the implementation of environmentally friendly field margins, 653 farmers in different parts of Germany were interviewed. They were asked to indicate the key aspects that need to be addressed in the design of their ideal field margin and their attitudes towards agri-environmental programs. Positive environmentally friendly attitudes of farmers lead to a more environmentally conscious management of field margins, where many individual measures of cultivation are planned less intensively.

Key words: field margin, questionnaire, agri-environmental program, biodiversity

Introduction

Intensive agricultural practices led to an overall drastic reduction in habitat refuges for animals and plants (Mkenda et al., 2019). Intensive agricultural regions have the lowest share of implemented low input measures, though they have to deal with the most serious nature conservation and environmental problems (Mante and Gerowitt, 2006). Field margins, as defined here, are part of the cropped field and directly adjacent to the non-cropland. Field margins in agricultural production systems are considered potential sources of environmental advantages, as they can provide semi-natural habitats for above- and below-ground animals, including soil organisms, small mammals, birds, and arthropods, which act as service providers (Mkenda et al., 2019). A modified or reduced arable management of field margins can be seen as a nature conservation measure that protects typical arable flora and enhances biodiversity. Field margin establishment and management are also one of the most cost-effective measures for the majority of farmers.

In general, agri-environmental programs (AEPs) are not widely accepted as a result of their high opportunity costs (i. e. the lost benefit caused by decreased yields) and the need for management changes (Brown, 2020). Farmers are the key to achieving biodiversity goals and to implement these measures, but they will only meet this commitment of service to society, if they are suitably motivated (Gabel et al., 2018). A variety of farmers' beliefs and values play a role in their participation in agri-environmental programs. Specifically, there are strong positive correlations between environmentally friendly attitudes and participation in programs that promote biodiversity, and negative correlations between production oriented attitudes and partaking (Breustedt et al., 2013; Brown et al., 2020; Gabel et al., 2018; Vanslembrouck et al., 2002).

However, there has been limited research on the intrinsic motivation of farmers that influence especially the adoption of field margin measures. Therefore, this study aims to analyze the attitudes of farmers that discourage or encourage the execution of conservation. The following questions will be answered: Can farmers' attitudes negatively or positively influence field margin implementation? How should field margins in AEPs be designed so that farmers participate in the programs? To answer these questions, a written survey from 2006 among 653 responding farmers was evaluated in intensively managed regions in Germany (Mante and Gerowitt, 2009).

Materials and methods

In 2006, a questionnaire-based survey of farmers was conducted (Mante and Gerowitt, 2009) in in Central Germany. Farms were located in regions with high yield potential, where ca. 90 % of the agricultural area was managed by intensive arable farming (further information in Mante and Gerowitt, 2007 and 2009). A total of 4720 questionnaires were sent to farmers receiving direct payments (EU) by the responsible paying agencies. The 653 completely answered questionnaires were evaluated. The questionnaire included two parts:

A) Multiple-choice questions about how farmers would design optimal field margin strips.
Design: flowers (flower), grasses (grass), conservation strips (conser), succession (succ)
Species sown: crops (crops), crops and/or wild species (crowil), allochton species (wilall)
Species longivity: annual (annual), perennial (perenn)
Location: on areas with nature conservation value (nat_val), along paths for reputation purposes (paths), on areas causing problems for agriculture, e.g. minor soil quality, restricted pesticide application possibilities (agr_prob)
Location specified: no restrictions (loc_free), some restrictions (loc_res), fixed (loc_fix)
Strip width: minimum 3 resp. 6 m (min_3, min_6), maximum 3 resp. 6 m (max_3, max_6)
Rotation: without limitation (rot_yes), certain restrictionw (rot_res), no rotation (rot_no)
Chemical plant protection: allowed (pp_yes), reduced (pp_red), not allowed (pp_no)
Cultivation measures: allowed (cult_yes), reduced (cult_red), not allowed (cult_no)
Duration of contract: one year (dur_1), two years (dur_2), more than two years (dur_x)

B) Statements about farmers' attitudes towards field margins AEP (agri-environmental program). Answers on Likert scale from 1 (strongly disagree) to 5 (strongly agree).
a1: AEP promote my reputation as a farmer.
a2: The reward for AEP must generate an increase in income for me.
a3. AEP must not interfere with my standard management practices.
a4: AEP must not result in any production-related disadvantages.
a5. Preserving biodiversity on my farmland is an important concern for me.
a6: Opinions of my colleagues are important in my decision to implement AEP.
a7: AEP represent an interesting and new challenge for me.
a8: In my opinion, AEP poses great risks.

Non-metric multidimensional scaling (NMDS, three-dimensional, Manhattan distances) was used to visualize and analyse the field margins that farmers had designed as optimal for AEP. The farmer attitudes were fitted into the ordination diagram. Fuzzy partinioning clusters were built to group together farmers with similar objectives. Calculations were done with the program R and the add-on packages 'vegan' and 'cluster'.

Results and discussion

The ordination diagram shows the strip characteristics sorted (Figure 1 a). On the right side are characteristics that deviate only slightly or not at all from the usual management of the field. Flexibility is desired both temporally (annual contracts) and spatially (free choice of strip location). On the left side of Figure 1 a, on the other hand, we find strip characteristics that clearly differ from the usual field management. The proposed field margin designs are without chemical pesticides and without maintenance measures, they contain a perennial vegetation with wild species and they follow a less intensive and more nature conservation-oriented design.

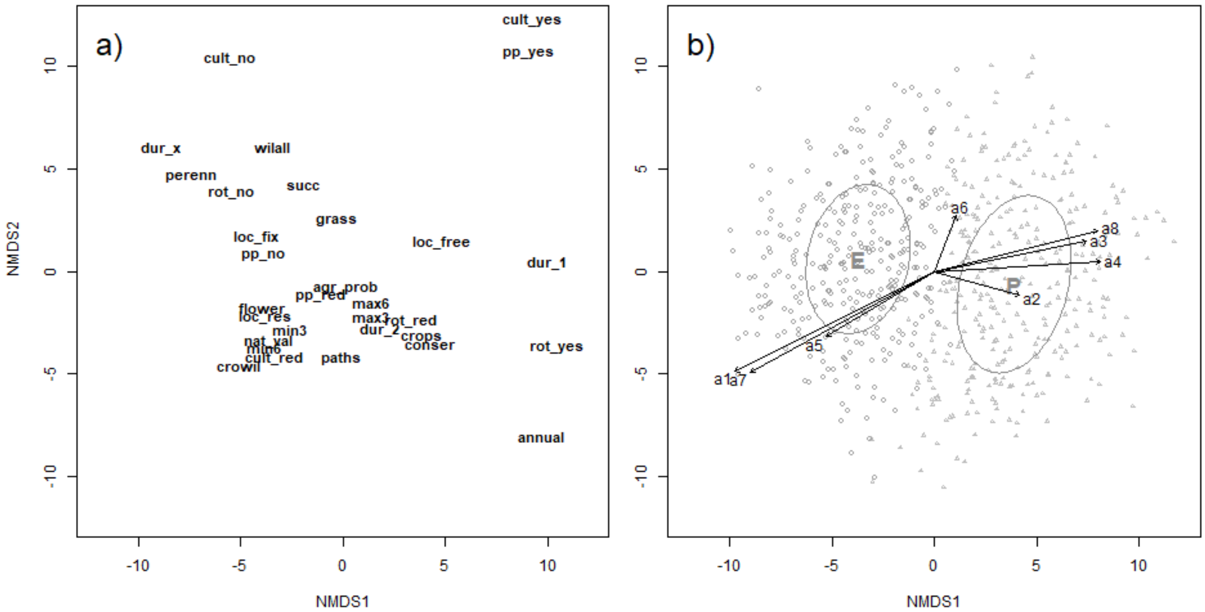


Figure 1. Farmers' designs of field margin strip according to a survey of 653 farmers. NMDS ordination diagram (three-dimensional, first two axes shown). a) Ordination of strip characteristics (abbreviations: Material and methods A). b) Ordination of farmers, clustered in ecology-oriented farmers (E, circles) and production-oriented farmers (P, triangles); capital letters are centroids, ellipses are plotted one standard deviation around them; arrows show fitted attitudes of the farmers (abbreviations: Material and methods B).

Farmers could be assigned to two clusters according to their hypothetical strip design (Figure 1 b), a production-oriented cluster and an ecology-oriented cluster. However, these were not strictly separated from each other. As per fuzzy clustering, the affiliation to cluster P was 87 % for the production-oriented farmers, and the affiliation to cluster E was 90 % for the ecology-oriented. The fact of clustering reflects the agrarian or agroecological expertise of the farmers: if any components of the agricultural system are changed, other parts of the system must be adapted accordingly. For policy makers, these results mean that AEPs do not have to be offered on a buffet principle (any feature can be combined with any), but that a few coherent offers are sufficient. This facilitates the conception for the state side, the information and the implementation for the farmer side and the administration for both.

Whether farmers were more oriented towards production-oriented strips or ecologically oriented strips was, as hypothesized, related to their attitudes (Figure 1 b). This was clearly evident among the production-oriented ones, who were not willing to take production-related disadvantages (a4) and did not want to change their standard management at all (a3), as AEPs were perceived as a risk for their objectives (a8). If they were willing to take this risk, it would have to be associated with additional income for them (a2). The opinion of professional colleagues was rather unimportant for farmers of both clusters (a6). Only 73 of 653 farmers stated that it was important or very important (Likert scale 4 and 5). This attitude was also the only one that did not correlate significantly ($\alpha = 0.05$) with the NMDS ordination. On the other hand, reputation in society (a1) was important. 57 % of farmers considered this attitude important or very important. Interestingly, this was mainly true for farmers in cluster E. This assessment reflects how farmers perceive society: Ecological goods receive appreciation, while there is comparatively less appreciation for the production of agricultural goods. Statements a5 (biodiversity is important concern) and a7 (interesting new challenge) were positively associated with cluster E farmers. It is noticeable, however, that these attitudes did not fit well with the most extensive strip characteristics, which are arranged in the upper left corner of Figure 1a. It may be that the real motivation for this type of strip would be nature and species conservation rather than biodiversity, which was asked about in the questionnaire.

Conclusion

Especially in favourable agricultural locations, the willingness of management changes within the framework of AEPs is low, as also shown by this survey on the design of field margins. Some farmers could only be motivated to manage field margins less intensively by monetary incentives. Farmers who are more open to biodiversity-enhancing cultivation often have an intrinsic motivation or can be motivated by social recognition. It would be useful to communicate this to society as well. In any case, it is important to design the field margins in a targeted and coherent manner.

Acknowledgements

The survey was conducted by Juliane Mante as part of a project supported by the German Federal Environmental Foundation (Deutsche Bundesstiftung Umwelt DBU).

References

Breustedt, G., Schulz, N. and L̈atacz-Lohmann, U. 2013: Factors affecting participation and compensation requirements in agri-environmental schemes: Insights from a discrete choice experiment. Ger. J. Agric. Econ. 62: 244-258.

Brown, C., Kovacs, E., Herzon, I., Villamayor-Tomas, S., Albizua, A., Galanaki, A., Grammatikopoulou, I., McCracken, D., Olsson, J. and Zinngrebe, Y. 2020: Simplistic understandings of farmer motivations could undermine the environmental potential of the common agricultural policy. Land Use Policy 101. 10.1016/j.landusepol.2020.105136.

Gabel, V. M., Home, R., Stolze, M., Birrer, S., Steinemann, B. and Köpke, U. 2018: The influence of on-farm advice on beliefs and motivations for Swiss lowland farmers to implement ecological compensation areas on their farms. J. Agric. Educ. Ext. 24: 233-248.

Kovacs, E. 2021: Seeing subsidies like a farmer: emerging subsidy cultures in Hungary. J. Peasant Stud. 48: 387-410.

Mante, J. and Gerowitt, B. 2007: A survey of on-farm acceptance of low-input measures in intensive agriculture. Agron. Sustain. Dev. 27: 399-406.

Mante, J. and Gerowitt, B. 2009: Learning from farmers’ needs: Identifying obstacles to the successful implementation of field margin measures in intensive arable regions. Landsc. Urban Plan. 93: 229-237.

Mkenda, P. A., Ndakidemi, P. A., Mbega, E., Stevenson, P. C., Arnold, S. E. J., Gurr, G. M. and Belmain, S. R. 2019: Multiple ecosystem services from field margin vegetation for ecological sustainability in agriculture: scientific evidence and knowledge gaps. PeerJ 7:e8091. 10.7717/peerj.8091.

Vanslembrouck, I., Huylenbroeck, G. and Verbeke, W. 2002: Determinants of the willingness of Belgian farmers to participate in agri-environmental measures. J. Agric. Econ. 53: 489-511.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 97-102

The habitat network for butterfly communities of the Alta Murgia National Park (Apulia, Italy)

Elena Gagnarli[1], Sauro Simoni[1], Rocco Addante[2] Onofrio Panzarino[2], Pamela Loverre[2], Maria Grazia Mastronardi[2], Chiara Mattia[3], Enrico De Lillo[2]
[1]Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria – Research Centre for Plant Protection and Certification, via Lanciola 12/a, 50125 Florence, Italy. [2]University of Bari 'Aldo Moro' Department of Soil, Plant and Food Sciences, Via G. Amendola 165/a, 70126 Bari, Italy. [3]Parco Nazionale dell'Alta Murgia, Gravina in Puglia, in via Firenze 10, 70026 Gravina in Puglia, Bari, Italy
E-Mail: elena.gagnarli@crea.gov.it

Abstract: In the Alta Murgia National Park (AMNP) (Apulia Region, Italy), screening was performed to study relationships between area/landscape composition and diurnal butterfly community structure. Representative semi-natural habitats of Alta Murgia buffering productive crops were selected to set up transects/paths along dry grasslands, oak forest and pine forest. Monthly samplings were performed for one year. More than 900 specimens, belonging to more than 50 species, were collected. The highest values of butterfly's abundance and richness were recorded in dry grasslands. The emerged evidence can provide useful information on butterfly conservation in AMNP and for the management and conservation of characteristic landscape of Alta Murgia.

Key words: eco-mosaic landscape, phenology, biodiversity, Papilionoidea

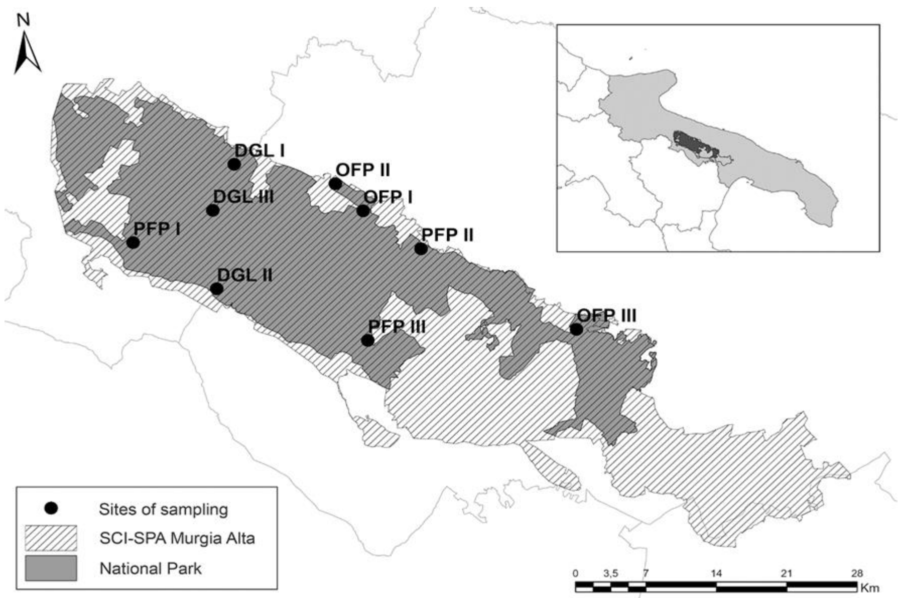
Introduction

Land Use intensification is a major driver of biodiversity loss and landscape simplification/fragmentation. Butterflies are one of the main indicators of diversity due to their high sensitivity to environmental changes. Since 70's, in the Alta Murgia National Park (AMNP), more than 25,000 ha of semi-natural grasslands were converted to arable lands. Removal of natural and seminatural habitats alters butterfly community structure and decreases species diversity in agricultural landscape. The dry grasslands of the AMNP represent a priority EU habitat as last example of pseudo-steppes on the Italian peninsula (Fracchiolla et al., 2017). The adoption of monitoring program based on butterflies biodiversity represents an important tool for next successful frameworks and policies in protected areas and to preserve biological corridors (Battisti et al., 2019). Deterioration, abandonment or afforestation of dry grasslands can affect suitability of the environment for diurnal Lepidoptera breeding and modify the structure of their populations (van Swaay et al., 2013). This study contributes to systematic survey on butterflies of AMNP and their distribution on the basis of different habitat taking account of abundance, species richness, phenology and relationship between species and habitats.

Materials and methods

Study area

The AMNP is located in a Mediterranean climate area, characterized by mild winters and hot-dry summers with summer temperatures increasing in the last decades (ARIF, 2019). The study was carried out in nine sites of naturalistic interest inside AMNP, representative of three habitats (three sites/habitat considered, see Figure 1): dry grasslands (DGL), characterized by an eco-mosaic of natural and semi-natural herbaceous priority habitat (Habitats Directive 92/43/EEC); oak forest (OFP), characterized by herbaceous vegetation bordered by forests dominated by downy oak (*Quercus pubescens* Willd), a deciduous species belonging to the priority habitat "Eastern white oak woods", according to HD 92/43/EEC; pine forest (PFP), characterized by herbaceous vegetation bordered by reforestation of conifers mainly composed by Aleppo pines (*Pinus halepensis* Mill.).



Code	Local Site	Habitat	Lat. N	Long. E	Altitude (m a.s.l.)
DGL I	Castel del Monte	dry grassland	41°04'54.69"	16°17'09.69"	540
DGL II	Rocca del Garagnone	dry grassland	40°57'56.88"	16°15'09.11"	528
DGL III	Monte Savignano	dry grassland	41°02'24.16"	16°15'21.92"	539
OFP I	Bosco Scoparella	oak forest path	41°01'41.86"	16°25'56.51"	250
OFP II	Lama delle Grotte	oak forest path	41°03'21.72"	16°24'09.55"	379
OFP III	Monte Cucco	oak forest path	40°54'00.44"	16°40'09.71"	428
PFP I	Foresta di Acquatetta	pine forest path	41°00'55.91"	16°09'33.09"	595
PFP II	Bosco Rogadeo	pine forest path	40°59'17.17"	16°29'46.04"	379
PFP III	Pulicchio di Gravina	pine forest path	40°54'16.84"	16°25'9.37"	555

Figure 1. Map and geographical positions of the sampling sites in the Alta Murgia N. Park.

Sampling method and species identification

Monthly samples were performed for one year, by transect survey, using an entomological net. The survey team recorded all diurnal butterflies (Pollard and Yates, 1993). The identification of the specimens followed the most common keys (Bozano, 1999; 2002; Eckweiler and Bozano, 2011; Grieshuber, 2014; Higgins and Riley, 1983; Tuzov, 2003; Villa et al., 2009; Weidenhoffer et al., 2016). Temperatures were recorded in five different sites. The effects of season, site and habitat/ecosystem on butterfly families' density were evaluated by Generalised Linear Model (GLM) (SPSS 15.0, 2006). The 2D-networks of butterfly species was realized using correlation by Bray-Curtis similarity index.

Results and discussion

Butterfly community. A total of 907 adult butterflies was detected during the survey. Fifty-three species belonging to: Nymphalidae (51 %), Pieridae (18 %), Lycaenidae (18 %), Papilionidae (8 %) and Hesperiidae (5 %) were identified. The effects of habitat ($F_{2,92} = 1.634$, $p = 0.035$) and time ($F_{11,92} = 9.255$, $p < 0.001$) were significant on the butterfly distribution: species abundances in DGL and PFP were significantly higher than in OFP (HSD Tukey test: $p<0.05$). No significant difference was observed in butterfly abundance between the transect replicates of the same habitat ($F_{2,92} = 0.81$, $p = 0.445$). Time/climate factor influenced the butterflies' dynamic with higher frequency of captures in spring-summer months (especially May and September 2017) (Figure 2). No butterfly was detected in December 2016 and only few individuals in January and February 2017 in forest paths (HSD Tukey test, $p < 0.05$). A positive correlation between the monthly butterfly abundance and monthly mean temperature of the air was pointed out (Pearson correlation: $r = 0.8$; $p < 0.001$).

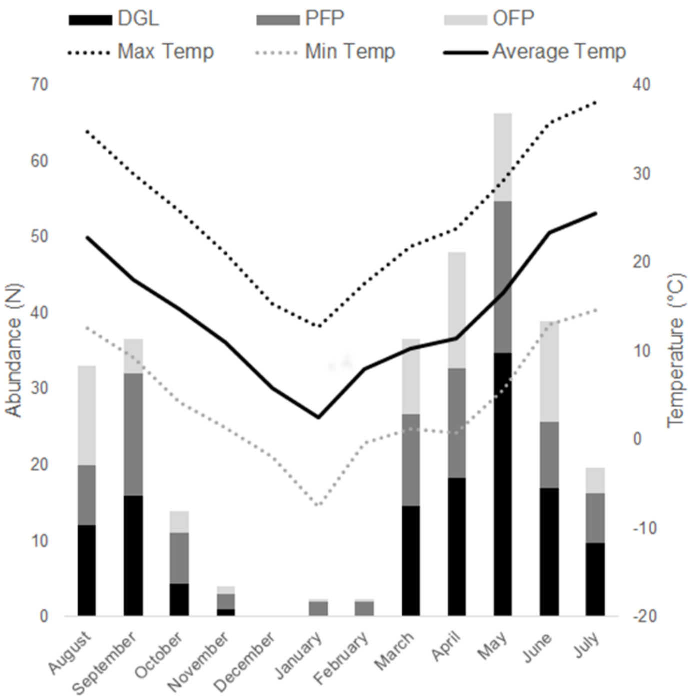


Figure 2. Monthly means of butterflies' abundance and air temperatures for habitat (2016-2017).

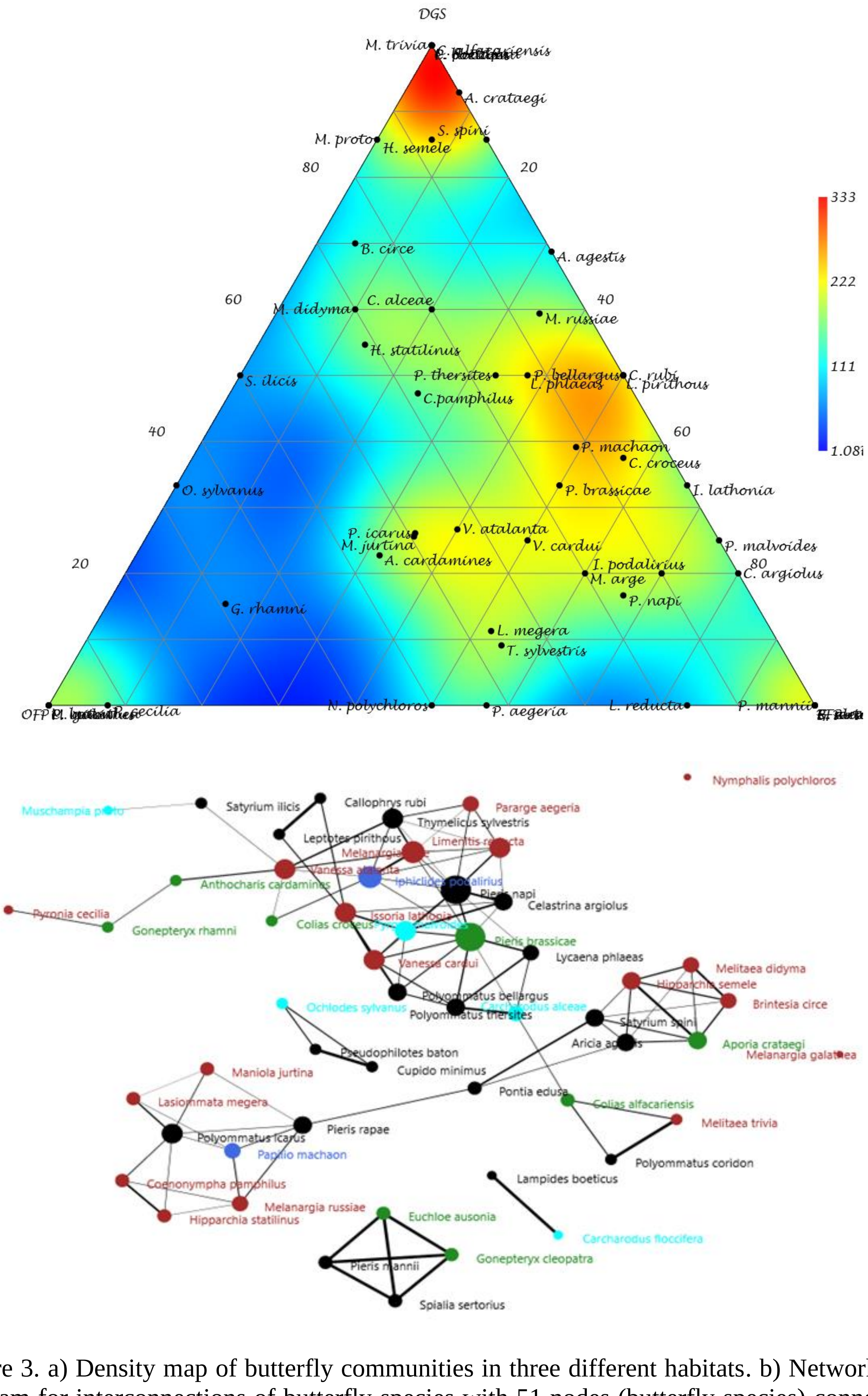


Figure 3. a) Density map of butterfly communities in three different habitats. b) Network 2D diagram for interconnections of butterfly species with 51 nodes (butterfly species) connected by 88 edges (lines).

In Figure 3 a, the distribution of butterfly species, by Non-Metric multi-Dimensional Scaling (NMDS) analysis over the study time, showed high proximity of most species except for *Melanargia russiae* (Esper), *Hipparchia statilinus* (Hufnagel), *Polyommatus icarus* (Rottemburg) and *Coenonympha pamphilus* (L.). Several species were common to different habitats and some species, common in meadows, were also registered in forest path, showing a effective natural network system with biological corridors. The dominant species were *H. statilinus*, *M. russiae*, *Papilio machaon* L., *Pieris rapae* (L.) and *Pontia edusa* (F.) in DGL, *Lasiommata megera* (L.), *P. machaon*, *P. icarus*, *M. russiae* and *P. rapae* in PFP, *H. statilinus*, *L. megera*, *P. icarus* and *Maniola* jurtina (L.) in OFP. The correlation of butterflies' species, evaluated by Bray-Curtis similarity index (Figure 3 b). This approach explicitly takes into account of multiple species and habitat resources, provides tools to estimate the importance of species in a specific habitat, and quantifies emerging properties of entire landscape network.

Furthermore, assessing the properties of butterfly communities, at spatial and temporal scale, can be used as important connection strategy among Sites of Community Importance in the EU Natura 2000 network, and to study global impacts of climate changes.

This survey indicates that habitat-specialist species may suffer from habitat fragmentation; therefore, the species-area relationship is important to ensure long-term biodiversity preservation (Trivellini et al., 2016).

References

ARIF 2019: Dati rete agrometeorologica regionale. Agenzia regionale attività irrigue e forestali. www.agrometeopuglia.it/presentazione-servizi/osservazioni. Accessed 17 September 2019.

Battisti, A., Vodă, R., Gabaglio, M., Cerrato, C., Bionda, R., Palmi, P. and Bonelli, S. 2019: New data concerning the butterfly fauna (Lepidoptera, Papilionoidea) of Veglia – Devero Natural Park and its surroundings (northwestern Italian Alps). Eco. Mont. 11(1): 5-15.

Bozano, G. C. 2002: Satyrinae, part III. Tribe Satyrini Subtribes Melanargiina and Coenonymphina. In: Guide to the butterflies of the Palearctic Region (ed. Bozano, G. C.). Omnes Artes, Milano.

Bozano, G. C. 1999: Satyridae, part I. Subfamily Elymniinae Tribe Lethini. In: Guide to the butterflies of the Palearctic Region (ed. Bozano, G. C.). Omnes Artes, Milano.

Eckweiler, W. and Bozano, G. C. 2011: Satyrinae, part IV. Tribe Satyrini Subtribe Maniolina. In: Guide to the butterflies of the Palearctic Region (ed. Bozano, G. C.). Omnes Artes, Milano

Fracchiolla, M., Terzi, M., D'Amico, F. S., Tedone, L., and Cazzato, E. 2017: Conservation and pastoral value of former arable lands in the agro-pastoral system of the Alta Murgia National Park (Southern Italy). Italian Journal of Agronomy, doi.org/10.4081/ija.2017.847

Grieshuber, J. 2014: Pieridae, part II. Subfamily Coliadinae. Tribe Coliadini. In: Guide to the butterflies of the Palearctic Region (ed. Bozano, G. C.). Omnes Artes, Milano.

Higgins, L. G. and Riley, N. D. 1983: Farfalle d'Italia e d'Europa. Rizzoli, Milano.

Pollard, E. and Yates, T. J. 1993: Monitoring butterflies for ecology and conservation: the British butterfly monitoring scheme. Chapman and Hall, London.

SPSS Inc. 2006.- SPSS for Windows, version 15.0. SPSS Inc., Chicago, Ill., USA.

Trivellini, G., Polidori, C., Pasquaretta, C., Orsenigo, S. and Bogliani, G. 2016: Nestedness of habitat specialists within habitat generalists in a butterfly assemblage. Insect Conservation and Diversity 9(6): 495-505. https://doi.org/10.1111/icad.12193.

Tuzov, V. K. 2003: Nymphalidae, part I. Tribe Arginnini. In: Guide to the butterflies of the Palearctic Region (ed. Bozano, G. C.). Omnes Artes, Milano.
van Swaay, C., Cuttelod, A., Collins, S., Maes, D., López Munguira, M., Šašić, M., Settele, J., Verovnik, R., Verstrael, T., Warren, M., Wiemers, M. and Wynhof, I. 2010: European red list of butterflies. Publications Office of the European Union, Luxembourg.
Villa, R., Pellecchia, M. and Pesce, G. B. 2009: Farfalle d'Italia. Editrice Compositori, Bologna.
Weidenhoffer, Z., Bozano, G. C., Zhdanko, A. and Chukin, S. 2016: Lycaenidae, part II, 2nd edition. Subfamily Theclinae, Tribe Eumaeini (partim). In: Guide to the butterflies of the Palearctic Region (ed. Bozano, G. C.). Omnes Artes, Milano.

Session Short presentations

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 104-108

Efficacy of trap crops and biopesticides to control brown marmorated stink bug [*Halymorpha halys* (Stål), Hemiptera, Pentatomidae] in apple orchards

Luka Batistič, Tanja Bohinc, Stanislav Trdan
University of Ljubljana, Biotechnical Faculty, Dept. of Agronomy, Jamnikarjeva 101, 1000 Ljubljana, Slovenia
** Corresponding author E-Mail: luka.batistic@bf.uni-lj.si*

Abstract: The brown marmorated stink bug (*Halyomorpha halys*) is an important pest in apple crops. We examined the potential of soybean (*Glycine max*), sunflower (*Helianthus annuus*), alfalfa (*Medicago sativa*) and sorghum (*Sorghum bicolor*) as trap crops for *H. halys,* and tested three biopesticides on the four trap crops to control *H. halys* in an apple orchard. We monitored the abundance of *H. halys* (egg clusters, larvae and adults) on each trap crop at 10-day intervals, and also assessed *H. halys* abundance on six apple trees (*Malus domestica*). The pesticide treatments included Nemaplus®, Botanigard WP, NeemAzal-T/S, a negative control and a positive control. The plant protection products were applied on trap crops at 10-day intervals. We also determined the abundance of the pest (egg clusters, larvae and adults) before the treatment and 2-3 days after treatment. Sorghum was the most attractive crop for *H. halys*, followed by sunflower, soybean and alfalfa. *H. halys* abundance increased when crops entered the fruit development stage. The effectiveness of three biopesticides against *H. halys* was generally low, and not signficantly different. Further research will be needed to further develop effective control methods for this invasive pest.

Key words: Brown marmorated stink bug, trap crops, sunflower, soybean, alfalfa, sorghum, environmentally acceptable plant protection products, Botanigard WP, Neemazal-T/S, Nemaplus®

Introduction

Due to the presence and emergence of new species of alien invasive pests, attempts are being made to acquire new methods to control these pests. One such pest is the brown marmorated stink bug [*Halyomorpha halys* (Stål)]. The bug is polyphagous with a high reproduction capability, a wide range of host plants and the ability to spread rapidly. Today, in Europe, the pest is widespread, and present almost in every country (Dioli in sod., 2016; Batistič, 2019). Current practices of pest control with insecticides are effective, but do not represent a sustainable solution to the problem.

By monitoring the population dynamics of *H. halys* on selected trap crops and primary host plant (apple trees) we tried to obtain data of the seasonal abundance and dynamics of the pest in the Goriška region (western part) of Slovenia. We also assessed the potential of sunflower, sorghum, soybean and alfalfa as trap crops for *H. halys* (Hokkanen, 1991; Soergel et al., 2015; Nielsen et al., 2016; Mathews et al., 2017). In addition, we assessed the efficacy of entomopathogenic nematodes, entomopathogenic fungi and neem (azadirachtin) as environmentally benign pest management options for *H. halys*.

Materials and methods

Research area

The experiment was carried out in 2021 in an area near the village of Miren, Slovenia, adjacent to an apple orchard of a local farmer, which consisted of the 'Elstar' apple variety. The orchard consisted of a total of seven rows of apple trees, in whole measuring approximately 120 m in length and almost 40 m in width.

Trap crops and plant protection products

We used the following trap crops: sunflower cv. RGT Wollf, soybean cv. Atacama, sorghum cv. Frisket, and alfalfa Soča in the experiment. We also studied the efficacy of Botanigard WP (*Beauveria bassiana*), Nemaplus® (*Steinernema feltiae*), and NeemAzal-T/S (azadirachtin). For the purpose of positive control we used Karate Zeon 5 CS (lambda-cyhalothrin).

Experimental design

Two separate experiments were performed. Experiment 1 was conducted at the left side of the orchard and the second experiment (experiment 2) was placed on the right side of the orchard. The plots of experiment 1 and 2 were both 120 × 2 m. The plot of experiment 2 was divided into 3 blocks (40 m each). In each block we established 4 different types of trap crops in the same sequence. First we sowed sunflowers, then soybean, then alfalfa and the last sorghum. On the left side of the orchard, the plot of experiment 1 was divided into 4 parts, and each of them into 4 smaller parts (4 different types of trap crops). In the first we used Nemaplus® in the second Botanigard WP and in the third NeemAzal-T/S. At the very end we left space for our positive control. The fifth part served as negative control, which did not receive any treatment, and was selected as the 3rd block of experiment 2.

Data acquisition and statistical analysis

We used two methods of pest detection: visual inspections of apple trees, sorghum, sunflower and soybean crops, and for alfalfa crop we used a sweepnet (2r = 40 cm). We recorded the growth stages of each trap crop from 5 May until 25 October, and also the abundance of *H. halys* individuals in the egg, larval and adult stage on trap crops from 25 June to 25 October at 10-day intervals. In experiment 1, we monitored the effectiveness of the selected plant protection products to supress *H. halys* on the selected trap crops from 7 July to 5 September. The abundance of *H. halys* was recorded before spraying and 2-3 days after spraying at 10-days intervals. For the purpose of data processing we used Statgraphics Centurion XVII software.

Results and discussion

Trap crops

The abundance of *H. halys* was not significantly different between sorghum, soybean, and sunflower plants. The abundance of *H. halys* in alfalfa was assessed with a different sampling method and can therefore not be directly compared to the other trap crops.

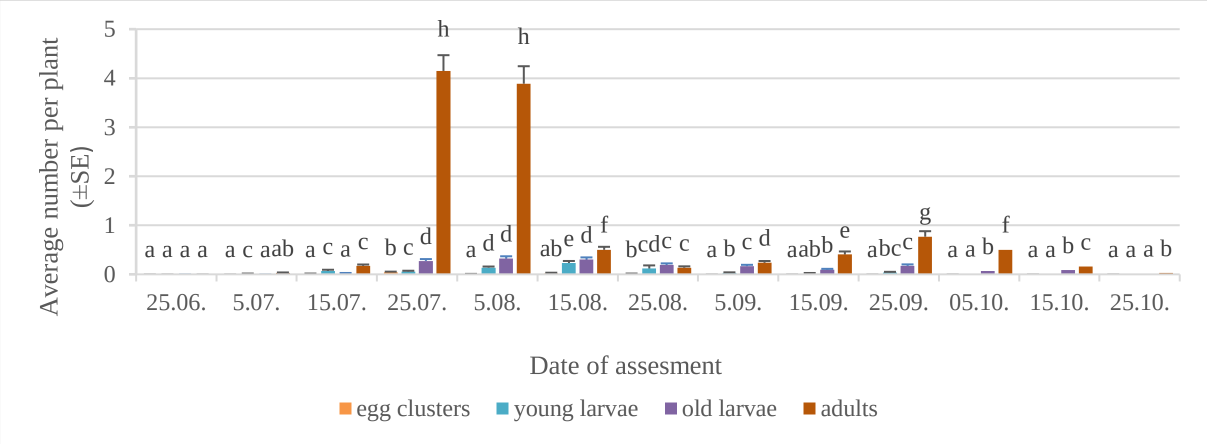


Figure 1. Average number (± SE) of different developmental stages of *H. halys* per plant on all of the studied trap crop plants together (sorghum, soybean and sunflower) per assessment date.

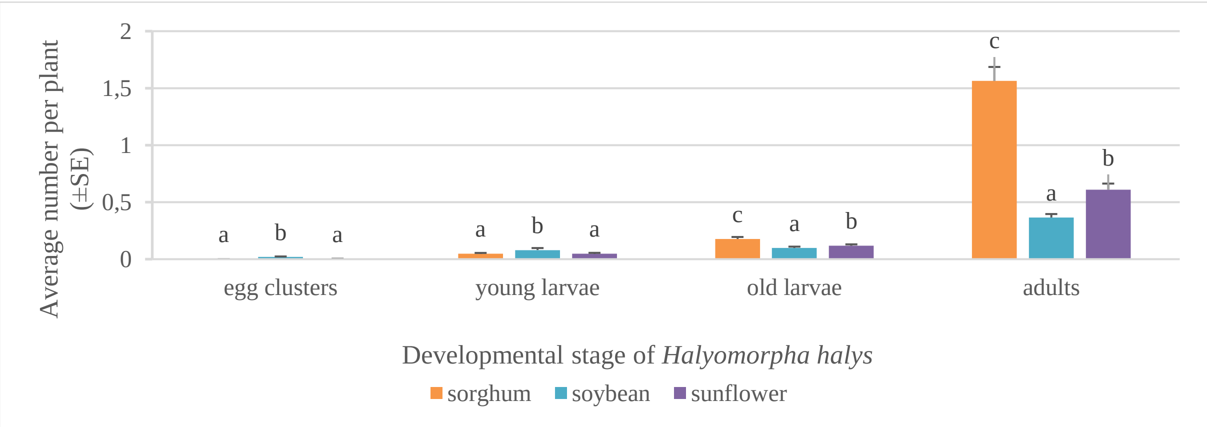


Figure 2. Average number (± SE) of *H. halys* individuals per developmental stage on individual sorghum, soybean and sunflower plants.

From the graphs we can deduce that among the selected trap crops, sorghum was the most attractive for *H. halys* adults followed by sunflower and soybean (Figure 2). The same applies for old larvae (Figure 2). The abundance of *H. halys* egg clusters and young larvae was the highest on soybean plants (Figure 2). With our results, we confirmed the hypothesis of differences in attractiveness and stink bug occurrence between crops.

Efficacy of the four plant protection products

Figure 3 shows the effectiveness of the biopesticides against *H. halys* on all trap crops together in comparison with the positive and negative control that was part of experiment 1. The average number of adults, old larvae, young larvae and egg clusters was not significantly different between the three biopesticide treatments and the negative control (Figure 3). The lowest average number of all of the developmental stages of the pest was recorded in the positive control treatment (Figure 3).

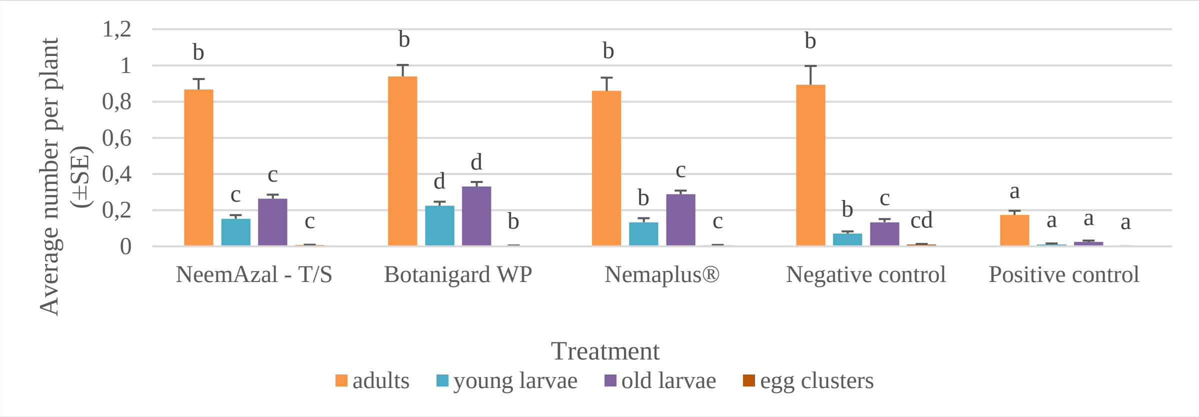


Figure 3. Average number (± SE) of different developmental stages of *H. halys* (adults, young larvae, old larvae and litters) on all trap crops together per treatment.

Conclusions

Based on the results which we obtained from experiment 2 of our study, we confirmed statistically significant differences in the abundance of *H. halys* between sorghum, soybean and sunflower. In experiment 1, we did not find any significant differences in the abundance of *H. halys* between Botanigard WP, NeemAzal-T/S, and Nemaplus® treatments and the negative control. We conclude that these biopesticides have very limited potential to suppress *H. halys*.

Acknowledgements

The article was created as part of the CRP V4-2002 project, which is funded by Research Agency of the Republic of Slovenia (ARRS) and the Ministry of Agriculture, Forestry and Food of the Republic of Slovenia.

References

Batistič, L. 2019: Presentation of brown marmorated stink bug [*Halyomorpha halys* (Stål), Hemiptera, Pentatomidae] and it's management strategies. B. Sc. Thesis, University of Ljubljana, Biotechnical Faculty, Ljubljana: 21 pp. (in Slovenian)

Dioli, P., Leo, P. and Maistrello, L. 2016: Prime segnalazioni in Spagna e in Sardegna della specie aliena *Halyomorpha halys* (Stål, 1855) e note sulla sua distribuzione in Europa (Hemiptera: Pentatomidae). Rev. Gaditana Entomol. 7: 539-548.

Hokkanen, H. M. T. 1991: Trap cropping in pest management. Annu. Rev. Entomol. 36: 119-138.

Mathews, C. R., Blaauw, B., Dively, G., Kotcon, J., Moore, J., Ogburn, E., Pfeiffer, D. G., Trope, T., Walgenbach, J. F., Welty, C., Zinati, G. and Nielsen, A. L. 2017: Evaluating a polyculture trap crop for organic management of *Halyomorpha halys* and native stink bugs in peppers. J. Pest Sci. 90: 1245-1255.

Nielsen, A. L., Dively, G., Pote, J. M., Zinati, G. and Mathews, C. 2016: Identifying a potential trap crop for a novel insect pest, *Halyomorpha halys* (Hemiptera: Pentatomidae), in organic farms. Environ. Entomol. 45: 472-478.

Soergel, D. C., Ostiguy, N., Fleischer, S. J., Troyer, R. R., Rajotte, E. G. and Krawczyk, G. 2015: Sunflower as a potential trap crop of *Halyomorpha halys* (Hemiptera: Pentatomidae) in pepper fields. Environ. Entomol. 44: 1581-1589.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 109-112

Occurrence of brown marmorated stink bug (*Halyomorpha halys*, Hemiptera, Pentatomidae) in urban area (Ljubljana, Slovenia)

Tanja Bohinc[1], Jerneja Jelnikar[1], Gudrun Strauss[2], Tomaž Sinkovič[1], Stanislav Trdan[1]
[1]University of Ljubljana, Biotechnical Faculty, Dept. of Agronomy, Jamnikarjeva 101, 1000 Ljubljana, Slovenia; [2]Institute for Sustainable Plant Production, Division for Food Security, Austrian Agency for Health and Food Safety, Spargelfeldstrasse 191, 1220 Vienna, Austria
Corresponding author E-Mail: tanja.bohinc@bf.uni-lj.si

Abstract: In 2021, we have started to monitor the occurrence of brown marmorated stink bug (*Halyomorpha halys*) in an urban environment of municipality of Ljubljana. Pheromone traps with aggregation pheromones were set up at two locations, at the Laboratory Field of Biotechnical Faculty (Rožna dolina) and Rakovnik. Monitoring of the abundance of studied insect (young larvae, old larvae, adults) in traps was done in weekly time-intervals. Plant species near the pheromone traps were also identified. Occurrence of different developmental stages of *H. halys* on several plant species in July, August and September was also collected. After the first year of research we find out that brown marmorated stink bug in the capistal city of Slovenia develops one generation per year. Egg clusters of the brown marmorated stink bug were recorded on the soybean, while adults and larvae were recorded on many plant species, such as buckwheat, industrial hemp, Canada goldenrod, eggplants, bell pepper, etc.

Key words: brown marmorated stink bugs, seasonal dynamics, host plants

Introduction

The brown marmorated stink bug, *Halyomorpha halys*, is known as invasive plant-feeding insect native to eastern Asia (Bergmann et al., 2015). It was detected in Slovenia in 2017 for the first time (Laznik and Trdan, 2021). This insect pest can feed on diverse plant species, including field crops, vegetables, tree fruits and ornamentals (Bergman et al., 2015). For host plants, that produce fruits, feeding injury by *H. halys* and other stink bugs can result in external scars, surface and internal discoloration, spongy or corky areas of the internal tissue and deformed fruit (Zobel et al., 2016). The list of host plants in Europe contains 51 species in 32 families, including many native and non-native plants (Fogain and Graff, 2011).

The aim of our study was to investigate a part of the bionomics of brown marmorated stink bug in an urban area of Ljubljana and to test the efficacy of aggregation pheromone in combination with funnel trap.

Materials and methods

Study site and research design

Occurrence of marmorated stink bug was monitored from the beginning of March 2021 to the beginning of November 2021 in two different urban areas in Ljubljana. The first area was the

Laboratory Field of Biotechnical Faculty (46.050383, 14.47089) and secondly, occurrence of *Halyomorpha halys* was monitored in location Rakovnik (46.037795, 14.527310). At the Laboratory Field of Biotechnical Faculty pheromone traps were placed in three different areas, i.e. horticultural area (vegetables), orchard area (apples, berries, hazelnuts…) and forest area (about 0.05 ha with different wooden plants). In location Rakovnik, traps were placed on the edge of the garden, where various vegetables (tomato, potato, etc.) were planted during the growing season.

Three pheromone traps [type: Pherobank ft (Funnel trap-green lid/green funnel/transparent bucket)] lured with aggregation pheromones (Trécè Pherocon BMSB dual lure) were placed more than 300 from each other. Aggregation pheromone was replaced every 12 weeks, and the number of *H. halys* was counted weekly.

Environmental parameters

Wheater parameters (temperature at 2 m above ground, daily precipitation, relative humidity value) were monitored at weekly intervals by the loT system for environmental parameters (Slovenian Forestry Institute: Laboratory for Electronic Devices).

Plant evidence and host plant record

In the vicinity (100 m^2) of all 6 pheromone traps all plant species were classified. From July, to September, the presence of different instar/stages of *H. halys* on individual plant species at both locations was evaluated in 7-10 days interval.

Data analysis

The results from monitoring of brown marmorated stink bug in selected intervals are shown as average number of bugs per trap per day (± standard error) related to the average temperature at 2 m above the ground.

Results and discussion

Seasonal dynamics

Figure 1 represents the average number of brown marmorated stink bugs (pre-imaginal instars, adults) caught weekly from 5th March till 24th November at the Laboratory Field of Biotechnical Faculty. The highest number of specimens was detected at the beginning of September. Although this is a general figure fot the location mentioned, the highest number of pest insects was obtained from the pheromone traps in the horticultural part, where various vegetables were grown.

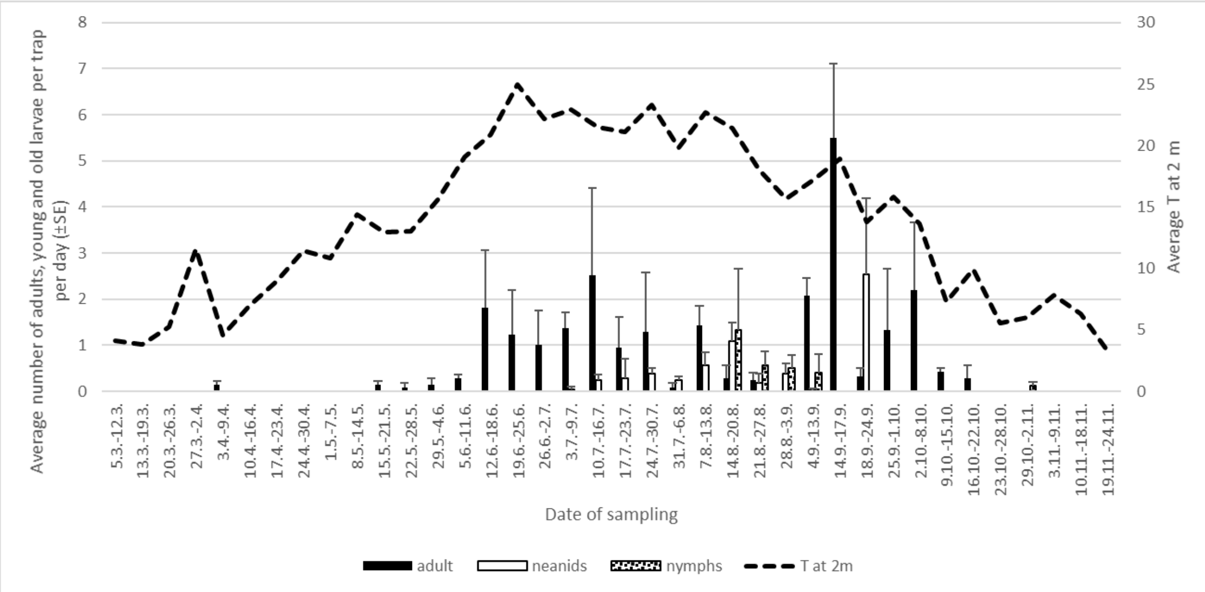


Figure 1. Average number of adults, neanids and nymph of *H. halys* per trap per week ± SE) at the Laboratory Field of the Biotechnical Faculty in Ljubljana.

In location Rakovnik, the highest number of *H. halys* was recorded in the third week of September 2021, as in Figure 2.

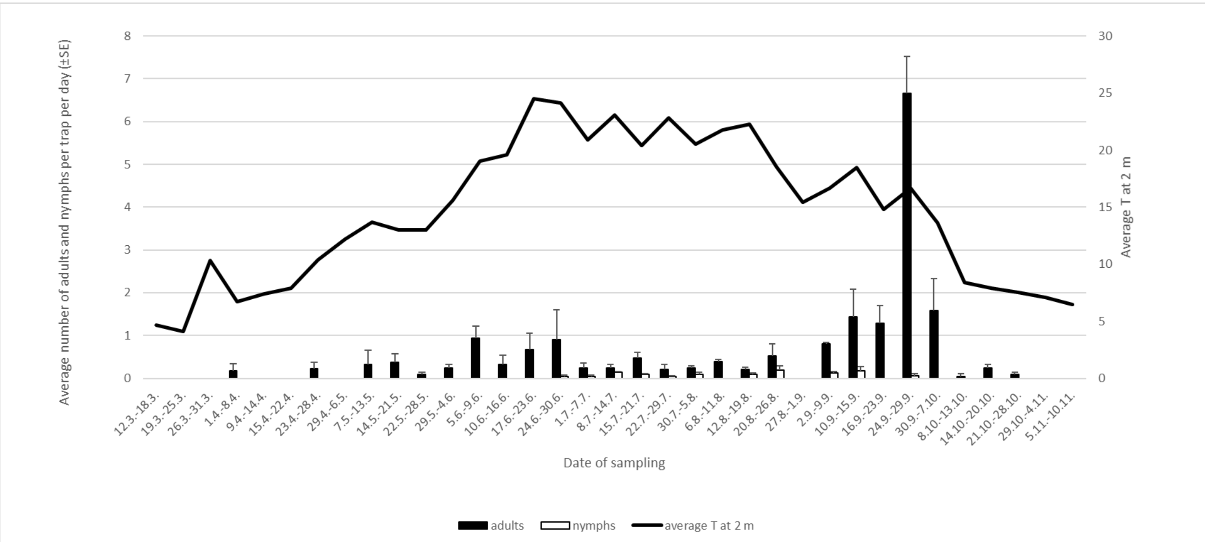


Figure 2. Average number of adults, neanids and nymphs of *H. halys* per trap per week (± SE) in the location Rakovnik.

***Plant species in the vicinity of pheromone traps and host plants of* H. halys**

Plant species located in the vicinity of all pheromone traps belonged to several botanical families, among which the most important were Cornaceae, Brassicaceae, Asteraceae, Polygonaceae, Asteraceae, Plantaginaceae, Rosaceae, Convolvulaceae, Cupressaceae, Amaranthaceae, Rosaceae, Portulacaceae, Fabaceae, Lamiaceae, Solanaceae, Malvaceae, Poaceae, Fagaceae, Betulaceae, etc.

Egg clusters belonging to *H. halys* were recorded on soybean and industrial hemp. Youngs were recorded on European blackberry, bell pepper and sunflower; adults and nymphs mainly on European plum, rose, spindle tree, European blackberry, kiwi, corn, Castor bean, vine, eggplants, buckwheat, Canada Goldenrod, raspberry.

Conclusions

Based on data, recorded at two different urban areas in Ljubljana, we can conclude that *Halyomorpha halys* develops one generation per year in the considered climatic area. *H. halys* was detected on several cultivated host plants, belonging to several botanical families.The highest number of egg clusters were found on the plants of soybean, so we find out that this field crop is the most important host of the pest in the study area.

Acknowledgements

Research was performed within Euphresco project Improved knowledge about epidemiology and distribution of priority invasive and (re)emerging arthropod pest in fruit crops and grapevines (e .g. *Aromia bungii, Popillia japonica, Halyomorpha halys*) (2020-A-340).

References

Bergmann, E. J., Venugopal, P. D., Martinson, H. M., Raupp, M. J., Shrewsbury, P. M. 2015: Host plant use by the invasive *Halyomorpha halys* (Stål) on woody ornamental trees and shrubs. Plos One 11(2): https://doi.org/10.1371/journal.pone.0149975.

Fogain, R., Graff, S. 2011: First records of the invasive pest, *Halyomorpha halys* (Hemiptera: Pentatomidae), in Ontario and Quebec. J. Entomol. Society Ontario 142: 45-48.

Laznik, Ž., Trdan, S. 2021: Management methods for marmorated stink bugs [*Halyomorpha halys* (Stal, 1855), Hemiptera, Pentatomidae]. Acta Agric. Slovenica 117: 1-11.

Zobel, E. S., Hooks, C. R. R., Dively, G. P. 2016: Seasonal abundance, host suitability, and feeding injury of the brown marmorated stink bug, *Halyomorpha halys* (Heteroptera: Pentatomidae), in selected vegetables. J. Econom. Entomol. 1-14.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 113-117

Landscape simplification and pest management effects on the entomofauna in apple orchards of Quebec

Mireia Solà Cassi[1,2], François Dumont[1], Geneviève Labrie[1], Caroline Provost[1]
[1]CRAM, Centre de recherche agroalimentaire de Mirabel,9850, rue Belle-Rivière, Mirabel (Québec, Canada), J7N2X8; [2]Laboratoire de Lutte Biologique, Département des science biologiques, Université du Québec à Montréal, 8888, Succursale Centre-Ville, Montréal (Québec, Canada), H3C3P8

Abstract: Intensive crop management is suspected to be the main cause of biodiversity loss while increasing pest presence and reducing natural systemic services. The aim of the project is to determine the impact of landscape simplification and pesticides use on the entomofauna and reveal the main systemic interactions in commercial apple orchards of Quebec (Canada). Nine sites, classified at three levels of landscape diversity were selected. Arthropods were sampled bimonthly over the 2020 summer season using general and pest specific traps. Captures were analyzed together with pesticides input and yield. At least 50 % of the 16,906 specimens identified were phytophagous, 14% were known orchard pests and 12 % were ecosystem service providers (pollinators, parasitoids and predators). Results show that simplified orchard landscapes present higher pest presence and less ecosystem services than high or medium diversified apple orchards. Community configuration at family taxonomical level was not significantly affected by the loss of landscape heterogeneity while ecosystem services were negatively associated with the level of environmental toxicity index of pesticides used. The results of this project make it possible to identify the main factors and associations operating within the orchard system with the aim of facilitating further IPM strategies that are more sustainable.

Key words: landscape diversity, arthropods community, massive trapping, pesticide use, pest, natural enemies

Introduction

Apple orchards are generally subject to intensive crop management practices such as landscape simplification and abundant pesticide inputs. Several studies have shown that habitat loss, and pesticides use contribute to the decrease of entomofauna diversity and ecosystem services in agroecosystems (Krebs et al., 1999; Tscharntke et al., 2012). In the case of apple orchards, multiple applications of broad-spectrum insecticides are often used in order to control multiple pest species, sometimes with multiple generations per production season, and possibly with developmental stages capable of escaping the effect of insecticides due to natural protection or because of the presence of refuges (Larsen et al., 2021). This level of intensive crop management results in a loss of ecosystem services and facilitates the emergence of secondary pests (Desneux et al., 2007)leading to the demand for further control measures.

Global demand for safer nutrition and a healthier environment, together with the phasing out of most chemical active compounds used as pesticides, increasing pesticide resistance, and the continuous and predicted increase of pest pressure due to climate change, is pushing scientists to search for alternative pest control strategies (Skendžić et al., 2021). Emergent strategies should be more sustainable while maintaining crop production and quality without representing an economic impact to the grower. Enhancing biodiversity and natural pest regulation is the more reasonable solution (Cassman et al., 2003). However, maintaining beneficial insects in simplified landscapes requires a systemic approach that has not yet been investigated. Within this context, the present study aims to determine how landscape simplification and abundant pesticide use affect entomofauna communities in commercial apple orchards of Quebec with a focus on arthropod pests and natural ecosystemic services.

Materials and methods

Nine commercial apple orchards of Quebec (Canada) were selected. Land use parameters within 500m of each orchard were obtained from public databases and were supplemented and corrected by observations during several visits in situ. Landscape features were categorized into the following groups: i) natural, ii) seminatural, iii) urban, iv) field margins and horticultural crops, v) orchard and vineyards, vi) berries, vii) corn-cereals-soy, viii) feeders, and ix) water sources. Their area was also calculated. The selected orchards were categorized into 3 landscape diversity levels according to the Shannon index. The insecticide treatment register containing the dose applied, frequency and number of active compounds used, and environmental toxicity index (IRE) were obtained from producers together with the yield data at the end of the 2020 season.

Arthropod community composition, configuration, and abundance was obtained from bimonthly captures using general sampling methods with pitfall traps, yellow pan traps, plant batting and from specific traps targeting the most common pests in apple orchards: *A. quadrigibbus, H. testudinea, L. lineolaris, R. pomonella*, mites and aphids. Sampling was performed in 3 defined equidistant stations located at center of each orchard from May to October 2020. Captured individuals in each trap were sorted by station, site, date and stored in alcohol until identification. Taxonomical identification was performed, in general, to family level. Main pests were identified to species level. Additionally, all collected specimens were classified according to the following functional groups: ecosystem service providers (predator, parasitoid, pollinator), phytophagous and other (omnivorous and scavengers).

Statistical analyses

Land cover within a buffer of 500 m around the selected orchards was quantified using landscape pattern indices with Qgis (Qgis development team, version 3.12) and the sum of the relative abundance calculated for each arthropod taxa for each orchard site. Correlations and potential multicollinearities were checked with Spearman correlation matrix for taxonomic variables. Generalised linear mixed effects models were used to test the effects of landscape diversity on: i) entomofauna abundance, ii) pest abundance, iii) natural services abundance (NS), iv) family richness and diversity (Shannon index), v) environmental toxicity index (IRE), vi) number of active substances used and, vii) yield. We also tested with generalized linear models: viii) the effect of number of active substances used on yield, ix) the effect of the number of active substances and IRE on the pest and NS abundance, and x) the effect of pests on yield. Quantitative variables were transformed with Tukey's Ladder of Powers. Differences between levels of categorical explanatory factors were compared with Tukey's post-hoc tests. Significant variables that did not present collinearities were then fitted to Principal Components Analysis (PCA) to plot the main factors acting on the system and highlight system interactions.

All statistical analyzes were realized on R software version 3.6.1 (R Core Team, 2021), using the “lme4”, “factoextra”, “FactorMineR”, “Hmisc”, “MuMIn”, “MASS”, “rcompanion”, and “vegan” packages.

Results and discussion

Apple orchard regions of Quebec are characterized by a mix of natural, seminatural and urban zones and crops. Main crops are maize and soya, orchard and vineyards, cereals and feeders and, berries and vegetables.

A total of 16,906 arthropod specimens were captured in general mass trapping. These were assigned to 106 taxonomic groups. At least 50 % of them were phytophagous. Importantly, 14 % of the identified arthropods are considered pests and 12 % were natural enemies. No significant differences in entomofauna abundance nor in diversity or richness were observed among the 3 landscape diversity levels. However, pest abundance differed among landscape diversity levels. Pest were significantly more abundant in simplified landscapes while medium diversified landscapes presented the lowest number ($X_2^2 = 20.85$, p-value < 0.0001). These differences were mainly due to the presence of aphids and spider mites and the increase of nearly 20 % of *R. pomonella* in targeted trapping on simplified orchards landscapes. Additionally, simplified landscapes presented a lower number of ecosystem service providers (predators, parasitoids and pollinators) ($X_2^2 = 6.76$, p-value < 0.05). This decrease in pest abundance within heterogeneous systems is in line with several studies and it is suspected to be related to greater difficulties in localizing their plant hosts and to lower resource availability (Grab et al., 2018). Yield and pesticide use (environmental toxicity level or number of active compounds used) where not associated with the reduction of landscape heterogeneity. Interestingly, the entomofauna abundance nor its pest or natural services groups had a significant effect on yield. Importantly, the index of environmental toxicity had a significant negative association with the abundance of ecosystem service providers ($X_8^2 = 19.69$, p-value < 0.05) while the number of active substances used did not represent a significant increase in yield.

In Figure 1, the resulting PCA analysis on the data is shown. The ordination analysis explains 31 % of the variability in the first axis. The main contributor is the environmental risk index of pesticide use (IRE) which is negatively correlated to entomofauna richness. The second axis explains 26 % of the variability and economically important functional entomofauna groups (pest, NS) are the main contributors. Pest, yield, and number of active substances used are highly correlated and are principally associated with simplified landscapes while richness of families is highly related to non-pest functional groups and are found in medium and high diversified orchards.

Overall, we have shown that agricultural intensification of apple orchards enhances pest presence and undermine the ecosystem services that would otherwise benefit crop production. The preservation and promotion of biodiversity, especially of ecosystem service providers, by reducing the pesticide use and increasing agroecosystems heterogeneity, is crucial. This is because biodiversity is strongly related to balance, resilience, health and sustainability of the ecosystems thereby, increasing growers profitability at long term (Grab et al., 2018).

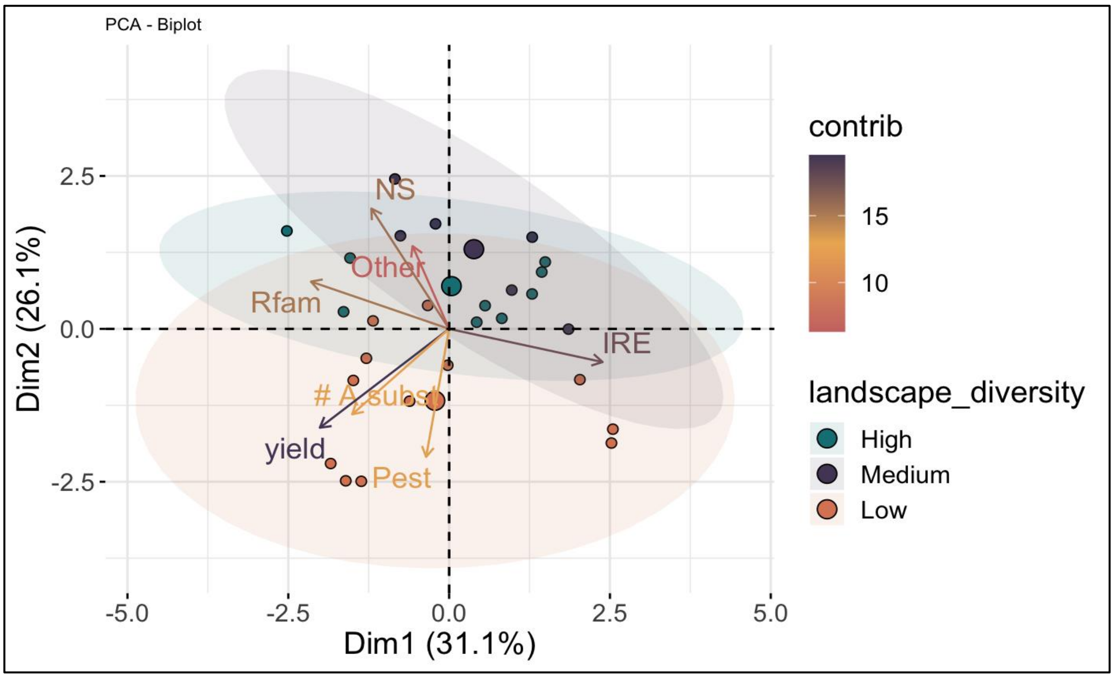


Figure 1. PCA-Biplot of main acting system factors according to landscape diversity levels. Pesticide use is represented as # A_subst and IRE which stands for the number of active substances and the environmental toxicity risk index, respectively. Abundance of entomofauna is represented according to 3 functional groups: Pest, NS (Predators, pollinators, parasitoids) and Other (scavenger, phytophagous and omnivorous). Richness at family taxonomical level (Rfam) and yield are also included. Dots represent studied stations (3) per orchard field (9).

Acknowledgements

The authors wish to thank M. Bonneville-Décarie, S. Campagnaro and P. Boulay for the technical support and producers for their access to their orchards. Funding for this project has been provided in part through the AgriScienceprogram-cluster on behalf of Agriculture and Agri-food Canada.

References

Cassman, K. G., Dobermann, A., Walters, D. T., Yang, H. 2003: Meeting Cereal Demand While Protecting Natural Resources and Improving Environmental Quality. Annu. Rev. Environ. Resour. 28: 315-358.

Desneux, N., Decourtye, A., Delpuech, J.-M. 2007: The sublethal effects of pesticides on beneficial arthropods. Annu. Rev. Entomol. 52: 81-106.

Grab, H., Poveda, K., Danforth, B., Loeb, G. 2018: Landscape context shifts the balance of costs and benefits from wildflower borders on multiple ecosystem services. Proc. R. Soc. B 285: 20181102.

Krebs, J. R., Wilson, J. D., Bradbury, R. B., Siriwardena, G. M. 1999: The second silent spring? Nature 400: 611-612.

Larsen, A. E., Claire Powers, L., McComb, S. 2021: Identifying and characterizing pesticide use on 9,000 fields of organic agriculture. Nat. Commun. 12: 5461.
Skendžić, S., Zovko, M., Živković, I. P., Lešić, V., Lemić, D. 2021: The Impact of Climate Change on Agricultural Insect Pests. Insects 12: 440.
Tscharntke, T., Tylianakis, J. M., Rand, T. A., Didham, R. K., Fahrig, L., Batáry, P., Bengtsson, J., Clough, Y., Crist, T. O., Dormann, C. F. 2012: Landscape moderation of biodiversity patterns and processes – eight hypotheses. Biol. Rev. 87: 661-685.

Landscape Management for Functional Biodiversity
IOBC-WPRS Bulletin Vol. 156, 2022
pp. 118-121

Does intensive crop management affect the diversity and abundance of species in fruit crops in Quebec, Canada?

Mireia Solà Cassi[1,2], François Dumont[1], Geneviève Labrie[1], Caroline Provost[1]
[1]CRAM, Centre de recherche agroalimentaire de Mirabel, 9850, rue Belle-Rivière, Mirabel (Québec, Canada), J7N2X8; [2]Laboratoire de Lutte Biologique, Département des science biologiques, Université du Québec à Montréal, 8888, Succursale Centre-Ville, Montréal (Québec, Canada), H3C3P8

Abstract: Several studies have shown that more diversified farms have equal or greater profitability than less diversified farms, using fewer chemical inputs. Environmental services are also improved in diversified facilities. This project aims to determine the impact of intensive crop management on the abundance and diversity of phytophagous and natural enemies for three agricultural systems: vineyards, apple orchards, and raspberry. Nine sites for each crop were selected. Three diversity gradients were selected based on crop diversity on each farm: 1) low diversity, 2) medium diversity, and 3) high diversity. Pitfall and yellow bowl traps have been installed to track entomofauna. The collection was carried out from May to September for two years. Intensive crop management affected the three fruit crops differently. Raspberry presented the highest diversified landscape, lowest pesticide input and highest entomofauna abundance, while apple orchards presented the opposite. A tendency with lower arthropod captures in simplified landscapes was insinuated for vineyards and orchards, while an overall increase in natural services was observed in heterogeneous landscapes. Further analyses are needed to show the advantages that can be obtained by promoting crop diversification within an agricultural enterprise.

Key words: landscape diversity, arthropods community, massive trapping, pesticide use, pest, natural enemies, integrated control

Introduction

Several studies have shown that more diversified farms have equal or greater profitability than less diversified farms, using fewer chemical inputs (Davis et al., 2012). Additionally, heterogeneous ecosystems are recognized to be more stable and more resilient in varying conditions (Özkan and Berger, 2014). On the other side, agricultural intensification is susceptible to altering the arthropod's community's structure. Yet, simplified landscapes provide less resource diversity and niches than complex landscapes where non-crop land acts as reservoirs for biodiversity. As a result, the spatial and temporal availability of resources required by beneficial organisms is reduced, while crop pests are often beneficiated from the concentration of host plants (Gardner et al., 1995; Tscharntke et al., 2005; Grab et al., 2018; Tscharntke et al., 2012). Then, simplified landscapes may require higher pesticide inputs. Overall, agricultural productivity, food and environmental security can be improved by enhancing agrobiodiversity and facilitating the numerous ecosystem services, such as natural pest control (Cassman et al., 2003; Davis et al., 2012). This project aims to determine the impact of intensive crop management on the abundance and diversity of phytophagous and natural enemies and compare the effect on three of the most important agricultural systems of Quebec, Canada: vineyards, apple orchards, and raspberry.

Materials and methods

Nine commercial fields of raspberry, apple orchard, and vineyard, respectively, were selected in Quebec's southern fruit production region (Canada). Land use parameters within 500 m buffer of each orchard were obtained from public databases and were supplemented and corrected by personal observations. Landscape features were categorized into: i) natural, ii) seminatural, iii) urbanized, iv) field margins and horticultural crops, v) orchard and vineyards, vi) berries, vii) corn-cereals-soy, viii) feeders, and ix) water sources. Their area was also calculated. Then, selected fields were categorized into 3 landscape diversity levels according to Shannon diversity index. Insecticide treatment registers containing the number of active compounds used and environmental toxicity index (IRE) were obtained from producers together with the yield data (except for raspberries) at the end of 2019 and 2020 seasons.

Arthropods community composition and configuration was obtained from bimonthly captures with pitfall traps & yellow bowl traps in 3 defined equidistant stations located at the center of each field from May to October 2019 and 2020. Captured individuals were sorted by station, site, date and stored in alcohol until identification. Taxonomical identification was performed, in general, at the family level. All collected specimens were classified according to three functional groups: i) natural services (predator, parasitoid, pollinator); ii) phytophagous; iii) omnivorous and scavengers.

Statistical analyses

Land cover within a buffer of 500 m around the selected orchards was quantified using landscape pattern indices with Qgis (Qgis development team, version 3.12). A taxonomic approach was first constructed based on the sum of the relative abundance of each collected arthropod taxa for each site. Then, we tested, with permutational analysis of variance using Bray-Curtis distance matrices and 999 permutations, the effects of agriculture intensification per each type of fruit production in: i) entomofauna abundance, ii) phytophagous abundance, iii) natural services abundance, iii) arthropods family richness and diversity (Shannon index) and iv) yield. Differences between levels of categorical explanatory factors were compared graphically. All statistical analyzes were realized on R software version 3.6.1 (R Core Team, 2021), using the “lme4”, “MASS” and “vegan” packages.

Results and discussion

Intensive crop management as means of landscape simplification and increased pesticide use affected differently the 3 fruit productions. For instance, raspberry productions possessed the highest landscape heterogeneity while orchards significantly the lowest ($F_{2,47} = 4.9131$, $p < 0.05$). Interestingly, raspberry productions received the lowest pesticide input but presented the highest environmental toxicity risk level (IRE) among the three fruit productions ($F_{2,41} = 11.74$, $p < 0.001$, $F_{2,41} = 22.9564$, $p < 0.001$, respectively). Additionally, raspberry and apple orchards presented higher pesticide applications in landscape simplified productions, while in vineyards, medium diversified landscapes presented the highest pesticide applications

($F_{4,41} = 2.48$, $p < 0.031$). Moreover, this landscape simplification significantly increased fruit yield ($F_{2,35} = 8.28$, $p < 0.001$) and was higher in apple orchards than in vineyards ($F_{2,35} = 64.06$, $p < 0.001$).

Overall, more than 90.000 specimens were captured and identified. The abundance of entomofauna, which did not show a significant effect on the fruit yield ($F_{1,34} = 0.71$, $p = 0.415$), differed among fruit productions and the level of landscape diversity, although it was only statistically supported for fruit production ($F_{2,145} = 2.6832$, $p < 0.05$; $F_{2,145} = 1.13$, $p = 0.34$). In Figure 1, it is shown that raspberry productions presented significantly more entomofauna than apple orchards or vineyards. Additionally, a tendency where higher captures were obtained in high and high and medium diversified landscapes was insinuated for vineyards and orchards, respectively. Raspberry did not show differences among landscape levels. Among the collected entomofauna, 31 % were phytophagous, and 18% were natural services. The majority were omnivorous and scavengers. Raspberry and apple orchards presented a higher number of phytophagous than vineyards ($F_{2,145} = 4.72$, $p < 0.01$). Additionally, for both fruit productions, a tendency with higher abundance in high and medium landscape diversified fields was observed while the abundance in vineyards remained similar across the 3 diversity levels. Overall, natural services were significantly higher in heterogeneous landscapes ($F_{2,145} = 2.76$, $p < 0.05$). Interestingly, the lowest number of natural services was observed in apple orchards, particularly landscape simplified fields ($F_{2,145} = 3.18$, $p < 0.05$). Entomofauna community configuration (diversity and richness of species) was not significantly affected by landscape simplification. However, family richness was significantly higher in raspberry productions, while orchards presented the lowest ($F_{2,145} = 6.7721$, $p < 0.001$).

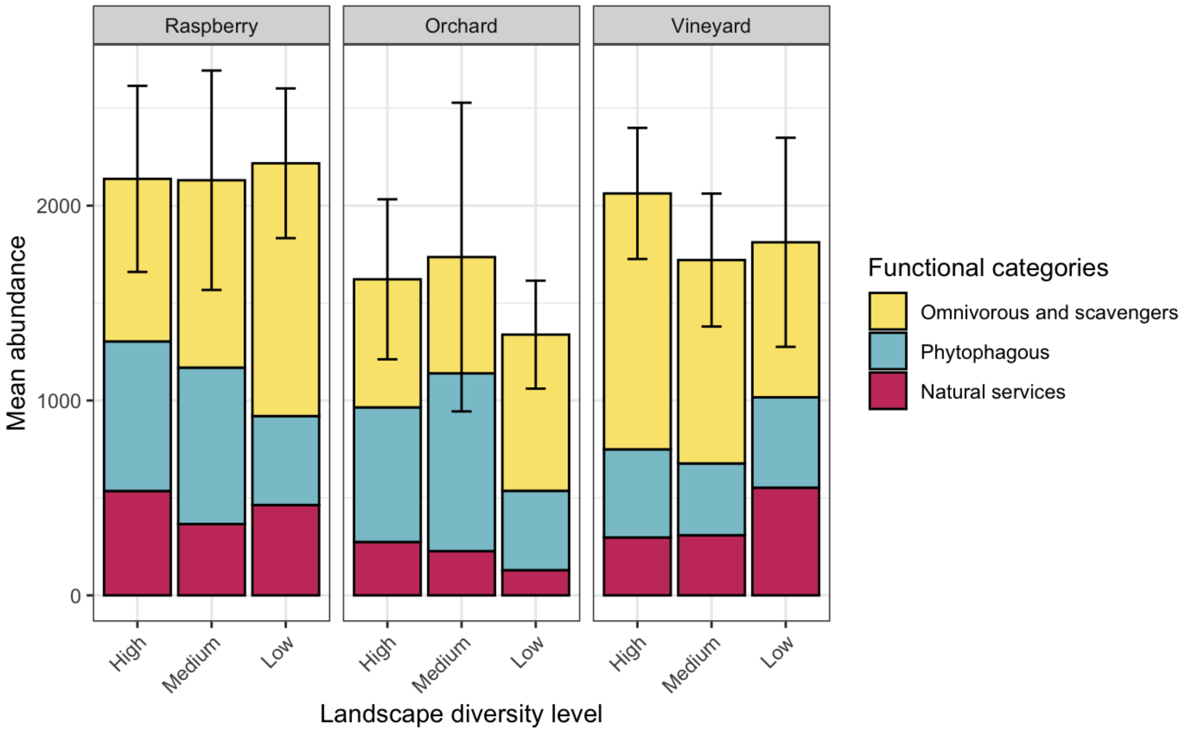


Figure 1. Entomofauna mean abundance of each functional group according to landscape diversity level in 3 fruit productions of Quebec obtained across two sampling years (2019-2020). Error bars for global mean abundance are represented.

Overall, the preliminary results of this project show that landscape diversity is not the main driver of entomofauna loss, but it does increase the yield production and reduces the presence of natural services. However, further analyses that are more specific for each fruit production are needed to identify main pests and determine their fruit damage as well as reveal main system effects and interactions to provide a deeper agrosystem vision to determine the impact of agriculture intensification on the arthropod community and fruit yield.

Acknowledgements

The authors wish to thank Myriam Bonneville-Décarie, Stefano Campagnaro and Pascale Boulay for the technical support and producers for their access to their fruit production fields. Funding for this project has been provided in part through the AgriScience program-cluster on behalf of Agriculture and Agri-food.

References

Cassman, K. G., Dobermann, A., Walters, D. T., Yang, H. 2003: Meeting Cereal Demand While Protecting Natural Resources and Improving Environmental Quality. Annu. Rev. Environ. Resour. 28: 315-358.

Davis, A. S., Hill, J. D., Chase, C. A., Johanns, A. M., Liebman, M. 2012: Increasing cropping system diversity balances productivity, profitability and environmental health. PloS One 7, e47149.

Gardner, S. M., Cabido, M. R., Valladares, G. R., Diaz, S. 1995: The influence of habitat structure on arthropod diversity in Argentine semi-arid Chaco forest. J. Veg. Sci. 6: 349-356.

Grab, H., Poveda, K., Danforth, B., Loeb, G. 2018: Landscape context shifts the balance of costs and benefits from wildflower borders on multiple ecosystem services. Proc. R. Soc. B 285: 20181102.

Özkan, K., Berger, U. 2014: Predicting the Potential Distribution of Plant Diversity in the Yukarıgökdere Forest District of the Mediterranean Region. Pol. J. Ecol. 62(3).

Tscharntke, T., Klein, A. M., Kruess, A., Steffan-Dewenter, I., Thies, C. 2005: Landscape perspectives on agricultural intensification and biodiversity – ecosystem service management. Ecol. Lett. 8: 857-874.

Tscharntke, T., Tylianakis, J. M., Rand, T. A., Didham, R. K., Fahrig, L., Batáry, P., Bengtsson, J., Clough, Y., Crist, T. O., Dormann, C. F. 2012: Landscape moderation of biodiversity patterns and processes – eight hypotheses. Biol. Rev. 87: 661-685.