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Landscape Management for Functional Biodiversity

Gestion de l'Environnement pour une Biodiversité Fonctionelle

editors:

Walter A.H. Rossing, Lisa Eggenschwiler &
Hans-Michael Poehling

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PROCEEDINGS OF THE 2ND WG MEETING

LANDSCAPE MANAGEMENT FOR FUNCTIONAL BIODIVERSITY

in Zürich-Reckenholz, Switserland
16-19 May 2006

Editors:
Walter A.H. Rossing, Lisa Eggenschwiler, Hans-Michael Poehling

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Preface

The field of "Landscape management for functional biodiversity" received attention from researchers working within IOBC for a long time. During the General Assembly of IOBC in Ascona in 2001 it was decided that it was time to create a Study Group as a platform to focus discussion on progress in this field. Following the successful inception meeting in Bologna in 2003, the Study Group group has become established as one of the Working Groups of IOBC.

Since the first meeting of the Working Group the interdisciplinary field of "Landscape management for functional biodiversity" expanded rapidly. Major reviews and books appeared dealing with the landscape perspective to conservation biological control, advances in spatial modeling capabilities were reported which enable scaling up from individual organisms and their behaviour to landscape consequences, and science took its role in discussing efficacy of policies for ecosystem services including pest management in relation to the spatial scale of remunerations. Spatial relations and scaling issues have become part and parcel of research on biocontrol and ecosystem services.

This Bulletin demonstrates the sustained interest in the Working Group as a platform for exchange of information on research on landscape management for functional biodiversity. The Bulletin brings together 43 papers as pre-ceedings for the 2nd Meeting of the Working Group in Zürich-Reckenholz, Switzerland. The papers address multi-trophic relations within fields, between fields and field margins, and between fields and other landscape elements, and include disciplines such as entomology, phytopathology, weed science, agronomy, landscape ecology as well as economics and public administration.

A separate set of papers addresses "success stories" in functional biodiversity. Based on accounts of a number of individual projects, a one-day workshop was convened by prof. Geert de Snoo in Leiden, The Netherlands, facilitated by IOBC, to arrive at an assessment of the state of the art. This resulted in a separate contribution to the Bulletin. This contribution serves as input for a session at the Meeting in which functional biodiversity is discussed as a promising but complex technology for dealing with sustainability concerns of society.

To support our efforts in creating a lively programme with opportunities for disciplinary depth as well as thematic breadth we have invited distinguished researchers into a Scientific Advisory Board. We are very grateful to drs. Giovanni Burgio, Peter Duelli, Barbara Ekbom, Bärbel Gerowitt, Andreas Kruess, Joop van Lenteren, and Andries Visser for their support during preparation of the meeting, and for their role as session moderators during the meeting. Many thanks are also due to Ms Wampie van Schouwenburg from Wageningen University for her help in finalizing the papers for these pre-ceedings.

The meeting in Zürich-Reckenholz is organized by Dr Lisa Eggenschwiler who generously donated her time also to scientific reflection on the programme, on the excursion and to editing this Bulletin. Her resolve, enthusiasm and patience have been indispensable and provide the ingredients that will make for a successful second meeting. We are thankful for her efforts.

The meeting is financially supported by IOBC and the Swiss Federal Research Station for Agroecology and Agriculture (Agroscope FAL Reckenholz). Furthermore, we want to thank the people of Agroscope FAL Reckenholz involved in organizing the meeting, especially Dr

Katja Jacot and Stephan Bosshart, for making this meeting possible. Valuable help was also provided by the Swiss Center for Agricultural Extension (Agridea) and Dr Ernst Boller.

We wish all of you success in understanding and applying functional biodiversity from a field, farm and landscape perspective.

Hans-Michael Poehling
Walter A.H. Rossing
Convenors IOBC/WPRS Working Group
"Landscape Management for Functional Biodiversity"
28 March 2006

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The impact of decaying straw banks on the arthropod complex in an agroecosystem

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Abstract: The significance of artificial straw banks in winter wheat crops for the arthropod complex was studied in the Krasnodar region between 2001 and 2003. Banks of decaying straw were inhabited by many various arthropods. Saprophagous and myсetophagous beetles, larvae of Diptera, some bugs, collembolans, wood-lice, millepedes and also some predaceous beetles and their larvae and some spiders found there food, shelters and habitats for their development. Beetles using dry food (*Dermestes laniarius, Silpha obscura*) avoided the banks. Only single specimens of phytophagous chrysomelid-beetles and shield-backed bugs were collected there. Dry hollow stems on the surface of the banks were used by some small parasitic wasps as shelters. The straw banks also influenced the distribution of some arthropods in the field. The parts of the field containing banks significantly attracted the large predaceous beetle *Carabus campestris* and small aleocharinae staphylinids. On the contrary, silphid-beetles obviously preferred the parts of the field without banks. The banks did neither influence the number of hortobionts in entomological net samples (aphids, bugs, thripses and hymenopterans) nor the rate of infestation of eggs of the shield-backed bug *Eurygaster integriceps* by its parasites. We suppose that the banks arranged in the field or nearby may serve as sources of the entomophagous arthropods and in that way promote the increase in the stability of agroecosystems and of the whole agrolandscape.

Key words: agroecosystem, agrolandscape, arthropods, straw bank, habitat

Introduction

It has been supposed that herpetobiont arthropods, being in the field, need shelters during unfavourable time of day or weather. Lack of shelters, suitable for herpetobionts, may be one of the reasons to keep them closer to the field edges. Artificial shelters made of decaying organic material may serve as habitats for detritobiont arthropods which in their turn may be food for predaceous herpetobionts, both adults and larvae. The main aim of this study was to reveal the effect of such artificial shelters on the arthropod complex in the field by a comparison of the composition and abundance of arthropods in the parts of the field with or without shelters.

Material and methods

The banks were made of decaying straw in the winter wheat crops in Kuban region (North Caucasus) every season for three years (2001-2003). They were disposed on the soil surface. There were long and short banks in the field. The long banks of about 100 m in length, 0.5 m in width and 0.2 m in height, were arranged in the central part of the field. These banks were made in November and remained in the field till harvesting in July of the next year. In spring short banks, of 5 m in length, 0.5 m in width and 0.2 m in height were made at the distances of 10 m and 150 m from the long one. The other half of the same field without banks was used as a control. In 2001 only one bank complex (one long and two short banks) was made but in 2002 and 2003, when the fields were longer, two such complexes were made in the same field at 400 m distance from each other. The experimental fields were changed every year owing to the crop rotation.

To study the complex of arthropods in the banks, samples of decaying straw and soil under them were taken. The ratio of abundance of herpetobionts and hortobionts in the experimental and control parts of the field was studied with the help of pitfall traps and entomological net sampling. To determine the abundance of egg parasites of the shield-backed bug *Eurygaster integriceps* Put., eggs of this bug were exposed for 48 hrs in the field. The samplings and the expositions were repeated at three sites (at the long and short banks) in the experimental zone and at the same pattern in the control area every 10 days during one month (the second part of May - the first part of June).

Results

There were many various arthropods in the straw banks. Aggregations of some small beetles were revealed there, e.g. Staphylinidae, Cryptophagidae, Anthicidae (mainly *Formicomus pedestris* Rossi), Lathridiidae, Pselaphidae and Ptiliidae. There were also some coccinelid-beetles (*Coccinula* spp. and *Hyppodamia* spp.), chrysomelid-beetles (*Oulema melanopus* (L.) and *Phyllotreta* spp.), various bugs (Lygaeidae, Rhopalidae and Miridae), etc.

Only single specimens of parasitic wasps (Scelionidae and Pteromalidae) were collected in the dry hollow stems of straw. Spiders were mainly present inside the banks by juvenile forms (Lycosidae, Salticidae and Thomisidae).

Many relatively large arthropods, both predaceous and detritophagous, were found mainly under the banks, e.g. the carabid-beetles *Carabus campestris* F.-W., *C. exaratus* Quens., *Anchomenus dorsalis* (Pont.) and *Brachinus* spp., larvae of some carabid-beetles, some spiders of Lycosidae, bugs of Lygaeidae and Pyrrhocoridae, the scarabaeid-beetle *Onthophagus ovatus* L., feeding on decaying straw, and single specimens of the shield-backed bug. There were also other arthropods like collembolans, wood-lice and millepedes.

It is interesting to note that *Dermestes laniarius* Ill., the most abundant species in pitfall samples was absent both in and under the banks. The same was true for *Silpha obscura* L.

Significant positive reaction to the banks was observed in predaceous *Carabus campestris* (Table 1). However another species of this genus, *C. exaratus*, did not react to the bank presence. Staphylinid-beetles (subfamily Aleocharinae) significantly preferred the experimental part of the field. We suppose that they were attracted by the smell of rotten straw. These beetles may be carnivorous. On the contrary, *Silpha obscura* demonstrated significantly negative reaction to the banks. The distribution of other herpetobionts as well as hortobionts did not depend on the bank presence.

Numbers of herpetobionts in the catches independent of their reaction to the banks were always the lowest at the distance of 10 m from the long bank. In the control part of the field, such pattern of distribution was always absent. Thus, the attraction of arthropods to the long banks is more expressed.

In the area of the field with the banks, a considerable part of egg-clutches of the shield-backed bug was destroyed by predators, presumably by the grasshopper *Tettigonia viridissima* L. (23.0%, n = 61), while in the control part of the field the pressure of predators was considerably less pronounced (3.3%, n = 59), ($P < 0.01$).

No effect of the banks was revealed in the infestation of the shield-backed bug eggs by parasitic wasps Telenominae (Scelionidae). For example, in 2003 in the experimental part of the field 60% of eggs were infested (n = 605), and in the control part the infestation of eggs was approximately the same - 56% (n = 712), ($P > 0.05$).

Table 1. The ratios of the number of arthropod specimens collected in the parts of the field with and without the straw banks for 2001-2003 (near the long and short banks together). Significant differences of the total values ($P < 0.05$) are marked with an asterisk. Dashes signify the absence of data.

Taxon	2001	2002	2003	Total
Carabus campestris	23/0	41/25	35/22	99/47*
C. exaratus	2/1	32/45	24/17	58/63
Staphylinidae	-	1076/880	-	1076/880
Aleocharinae	-	-	1443/548	1443/548*
Dermestes laniarius	-	852/1052	1391/1171	2243/2223
Catopidae	-	-	94/86	94/86
Formicomus pedestris	-	-	132/98	132/98
Silpha obscura	-	21/61	58/88	79/149*
Lycosidae	264/344	142/105	-	406/449
Pardosa agrestis	238/310	108/63	-	346/373
Macrosiphum avenae	1909/1975	2653/2689	-	4562/4664
Thysanoptera	1783/1710	-	-	1783/1710
Eurygaster integriceps (overwintering adults)	8/27	37/38	48/31	93/96
E. integriceps (larvae and nymphs)	55/23	233/223	1380/1304	1668/1550
E. integriceps (adults of new gener.)	-	-	299/167	299/167
Aranea (hortobionts)	-	-	63/69	63/69

Discussion

The artificial banks made of decaying straw are inhabited by many various detritophagous and predacious arthropods. A similar composition of beetles has been discovered by Tsurikov (2002) in haycocks. These arthropods use the banks as a shelter, a source of food or a habitat for development. Phytophagous insects can use these shelters only occasionally. The complexes of arthropods in long and short banks were similar.

Pitfall catches show that some herpetobiont carabid- and staphylinid-beetles are also attracted to the part of the field with the banks. The difference in the reaction to the presence of the banks in the field of two *Carabus* species, *C. campestris* and *C. exaratus*, seems to be explained by their life cycles. The former beetle lays its eggs into the banks in the beginning of summer, while the latter oviposits during the second half of the summer after harvesting when the straw banks in the field are already absent. Therefore the larvae of *C. campestris* can be found in our banks but no *C. exaratus*.

It may be supposed that the adults of *Silpha* feeding on dry plants in the field are repelled by the smell of decaying straw. The dermestid-beetle *Dermestes laniarius* is known to be indifferent to the straw banks because this species does not use any shelters and prefers relatively dry habitats (Minoransky, 1969). The distribution of all hortobionts does not depend on the bank presence since they rarely go down to the ground surface.

In our experiments, the banks were exposed in the field only from November till the middle of July. In November the most of the arthropods had already gone to their hibernation sites. We suppose that the effect of the banks could be significantly reinforced if they remain in the field for some years. On the other hand, one narrow bank of 100 m in length may be insufficient for a field of 40-50 ha to provide enough natural enemies for the agroecosystem stability. It is also necessary to investigate a possible negative role of the banks as a source of mycobiota dangerous for crops.

Nevertheless, we hope that the arrangement of long straw banks in or near the fields may be a new approach for increasing the self-sustainability of an agrolandscape.

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Tsurikov, M.N. 2002: Small hills of hay as refugiums for Coleoptera hibernation. In: History and development of ideas of P.P. Semenov- Tjan-Shansky (in Russian). Lipetsk. 2: 108-110.

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Selection of insectary plants for ecological infrastructure in Mediterranean vegetable crops

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Abstract: Mediterranean vegetable growing areas are landscapes characterised by the coexistence of several annual crops, grown on rather small farms, and with a variety of species grown simultaneously all year round. Vegetable production is highly intensive, with up to three crops being produced on the same piece of land each year. The periodic destruction of non-crop vegetation along field margins hinders the establishment of natural enemies that must re-colonize fields each time. Given this scenario, the conservation and exploitation of native natural enemies that are normally found in the production area should assume a central role in biological control. The objective of this paper is to summarize our work related to the identification of insectary plants that may serve as ecological infrastructures in vegetable crops.

Key words: predators, augmentation, habitat management

Introduction

Mediterranean vegetable growing areas are landscapes characterised by the coexistence of several annual crops, grown on rather small farms (2-3 ha), and with a variety of species grown simultaneously all year round (e.g. lettuce, tomato, potato, brassica crops, cucurbits, etc). Greenhouses tend to be only partially sealed, and the boundaries between greenhouses and field crops often become blurred. Because of lagged transplantation times, there may also be overlapping fields of the same crop. As many vegetables share the same pests (e.g. whitefly and thrips) problems are exacerbated as there is a continuous carry-over of pests throughout the year that is hardly interrupted, even in winter.

Vegetable production is highly intensive, with up to three crops being produced on the same piece of land each year. There is also periodic destruction of non-crop vegetation along field margins (e.g. as part of cultural practices to reduce pest infestations). The discontinuous nature of such ephemeral habitats makes the establishment of natural enemies more difficult than in more permanent habitats and natural enemies must re-colonize the fields each time (Gabarra et al., 2004).

Given this scenario, the conservation and exploitation of natural enemies that are native to the production area should assume a central role in biological control (Gerling et al., 2001). Our long-term aim is to develop strategies that allow the conservation and enhancement of key generalist predatory guilds that are useful for several vegetable crops that may be present on farms (Avilla et al., 2004). In greenhouses, biological pest control is based on both conservation and supplemental seasonal inoculative releases of mass reared entomophagues when needed (Albajes et al., 2003).

The creation of ecological infrastructures to provide required resources for natural enemies has proven to be a viable strategy to enhance biological control in crops. Our previous work has addressed identifying host plants for the predator *Macrolophus caliginosus*, which spontaneously colonizes several vegetable crops (Alomar & Albajes, 2003). The objective of this paper is to summarize our work related to the identification of insectary plants that may be used to enhance *Orius* spp. and hoverflies, which are also common in several vegetable crops (Riudavets & Castañe, 1998; Arnó et al., 2002).

Material and methods

Candidate plants were selected from those mentioned in the bibliography as of interest for *Orius* and/or hoverflies. Native or naturalized plant species were selected in order to prevent new species becoming invasive. Two separate fields at our research institute in Cabrils were planted with seedlings in two separate years (2003, 2005). One field was basically prepared for hoverflies and the other for *Orius* (32 and 25 plant species respectively). Plants were grown in 2.25 m^2 plots in a complete randomized-block design with three replications. In the Orius field, plants were shaken over a tray every three weeks from February to July and all thrips and *Orius* were counted *in situ*. In the hoverfly field, each plot was aspirated for 15 s with a D-Vac. Visits to the plots by adult hoverflies were recorded by visual observation (three minutes) of each plot when plants were in bloom. Observations were made twice a week from March to May before noon on sunny, clear and calm (wind < 3 m/s) days. Syrphid adults were registered as either entering the plot or resting and/or feeding on the flowers.

Results and discussion

Identification of candidate plants

Many of the plants tested in the Orius field had abundant *Orius* populations. Figure 1 shows the cumulative number of adults and nymphs of *Orius* spp. on 12 of the most infested plants. Many of them also had nymphs, indicating that adult *Orius* did not only profit from plant and prey resources, but also reproduced. However, *Orius* were quite late in appearing on some of the plants (e.g. *Ocimum basilicum, Thymbra capitata*), possibly because of their late flowering. Although of potential interest in summer, these plants could be of little use for enhancing *Orius* populations in spring. If the plants selected were restricted to those bearing *Orius* between February and mid-May, only five could be selected: *Vicia faba, V. sativa, Lupinus hispanicus, Lobularia maritima,* and *Achillea millefolium.*

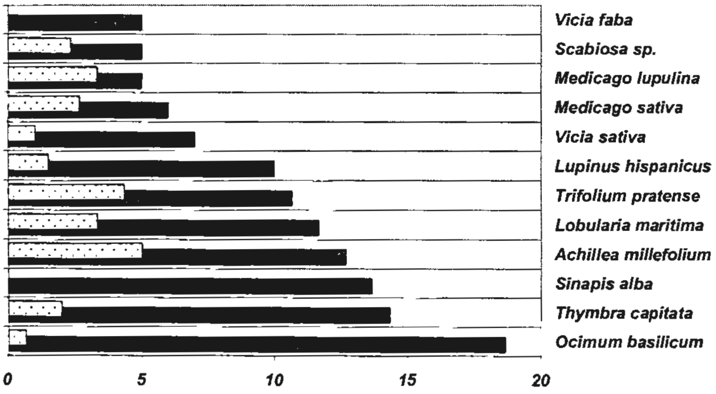

Figure 1. Cumulative abundance of *Orius* spp. (black bars are adults, dotted bars are nymphs) in insectary plants.

The highest populations of *M. caliginosus* (not shown) were found on *Dittrichia viscosa*, which confirmed this plant as the main host for this predator. *M. caliginosus* was also found on *Calendula officinalis*, which confirmed previous field observations on the potential of this plant.

Adults of predatory hoverflies were observed on most plots in the hoverfly field. However, on less plant species adults were observed resting or feeding on flowers (Fig. 2).

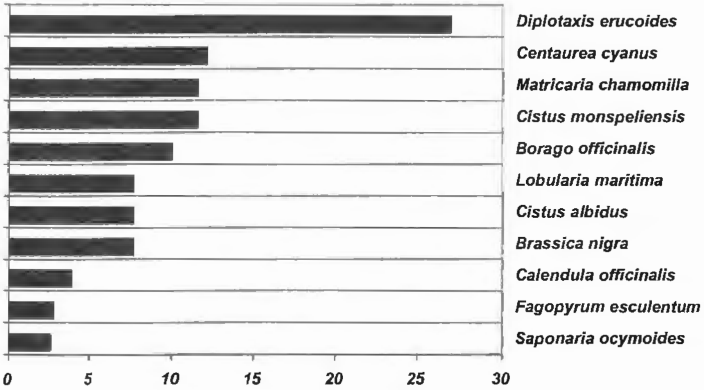

Figure 2. Relative mean visitation rates of adult hoverflies to flower plots in bloom during spring.

Developing a plant mixture for vegetable crops

Based on these results, we defined a preliminary mixture of six plant species to be annually planted along field margins. This year we will assess its utility for the conservation of predators and enhancement of biological control in a field trial on lettuce. The selection of candidate plants will continue in order to further tailor the plant mixture.

The careful selection of plants for the ecological infrastructure is important for preventing or at least minimising the risk of exacerbating pest and disease problems in the target cropping area. Amongst the plants selected for *Orius*, *Vicia faba* is a well known host of the tomato spotted wilt virus (TSWV), transmitted by the thrips *Frankliniella occidentalis*, and affects several vegetable crops in the Mediterranean region. This plant was therefore discarded for our purposes. *Achillea* and *Lobularia*, both had thrips although few were *F. occidentalis*. They might not, therefore, be chosen when *Orius* is our primary concern, and we finally selected *Vicia sativa* and *Lupinus hispanicus* for *Orius*.

For *M. caliginosus*, we selected *C. officinalis* and *Ononis natrix*, the latter is another plant that we know to be a good refuge for this predator. *Inula viscosa* allows the conservation of important populations of *Macrolophus*, but was not selected due to problems associated with its establishment in tomato crops.

For hoverflies, the plants with most visits (e.g. *Diplotaxis arvensis*) also had very abundant thrips populations, or were arbustive and slow growing (e.g. *Cistus* spp.). We therefore selected *Centaurea cyanus* and also included *L. maritima* into our annual planting. Although the presence of *F. occidentalis* in flowerheads of sweet alyssum may present a certain element of risk, it should be noted that this plant has been used in other settings without problems.

Minimizing risk in biological control is an increasingly important issue (Bigler et al., 2006). However, although the selection of plants for natural enemies and against pests is an important goal, achieving total risk prevention in multiple cropping situations may prove extremely difficult (Gurr et al., 2005). Conversely, the co-occurrence of the predator and pest in flowers may also confer some potential for reducing pest populations in refuges, thereby largely preventing problems from developing.

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Modelling effects of land use on spatial ecology, energy budgets and population viability in the ladybeetle *Coccinella septempunctata*

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Abstract: Changes in land use affect species interactions and population dynamics by modifying the availability of resources in time and space. We developed an integrated framework for evaluating the effects of land use on species viability by modelling foraging performance and energy sequestration in a stage structured, spatially explicit three-trophic population model. The model is parameterized – as a case study – with realistic parameters for a ladybeetle-aphid-host plant interaction, and is run in real landscapes in the Czech Republic. We analyzed whether changes in land use could explain the dramatic and unexplained decline in abundance of the ladybeetle *Coccinella septempunctata* in the Czech Republic from 1978 to 2005. The results indicate that a major reduction in fertilizer input after the transition to a market economy, resulting in lower aphid population densities in cereal crops and negatively affecting energy sequestration, survival and reproduction of ladybeetles, provides a sufficient explanation for the observed population decline.

Key words: *Coccinella septempunctata*, ladybeetle, aphid, modelling, landscape composition, trophic interactions, scale

Introduction

We ask the question how landscape composition (distribution of crop and non-crop habitats) and land use (composition and quality of crop habitats) can potentially affect the long-term population dynamics of predators via prey availability. For this purpose we developed a spatially explicit population model for the population dynamics and foraging performance of predators in heterogeneous landscapes. The model links landscape composition and land use to the temporal and spatial distribution of resources in the landscape. In turn, the resource distribution affects mortality and reproduction of the predator through its foraging performance and energy sequestration. This concept is applicable to a broad spectrum of organisms whose survival and reproduction is directly related to resource capture in heterogeneous environments.

We elaborated this model for the ladybeetle *Coccinella septempunctata* (L.) that forages on aphids. Aphid species are important herbivores of crop and non-crop vegetation, and some species have a pest status. In Europe, *C. septempunctata* is the dominant predator of aphids in both crop and non-crop habitats. Monitoring of their abundance in hibernation sites since 1978 in the Czech Republic revealed a long term population decline since 1990 (Honěk & Martinkova, 2005). The dramatic population decline of this ladybeetle coincided with changes in land use caused by change in economics and agricultural politics. Since the change in land use consisted of several modifications implemented at the same time, each possibly affecting the ladybeetle population differently, it is not clear what contribution each land use change made to the population decline of ladybeetles. Modelling is the only practical way to address this issue as the assessment of field patterns at these large spatial and long temporal scales are unfeasible.

The aim of this study is to explore the likely consequences of each of the observed changes in land use on population dynamics of ladybeetles separately in realistic landscapes.

Material and methods

Changes in land use were recorded in 4 areas near the hibernation site, further referred to as Ruzyne (centre of the area at 50° 04' N, 14° 15' E, 300 - 350 m a.s.l.), Polabi (50° 07' N, 14° 55' E, 180 - 250 m a.s.l.), Milicin (49° 36' N, 14° 40' E, 500 - 600 m a.s.l.), and Rana (50° 23' N, 13° 47' E, 250 - 450 m a.s.l.). Each site covered approximately 25 km^2. The four landscapes differed in composition and grain: the proportion of cropping area (cereal, alfalfa and rape) in Ruzyne, Polabi, Rana and Milicin was respectively 0.81, 0.79, 0.64 and 0.49. Non-crop habitats were dominated by forest (Milicin), pasture (Rana) or urban areas (Polabi and Ruzyne). Around 1990, major changes in land use occurred, prompted by a reduction of subsidies for agricultural production after the Czech Republic went from a socialist to a market-driven economy. After 1990, agriculture became less intensive, with reduced fertilizer input and lower yields. Furthermore, the acreage of small grain cereals and alfalfa decreased, whereas the acreage of oilseed rape increased. Both changes in fertilizer input and crop selection are likely to impact coccinellid species by changes in aphid populations. Reduced fertilizer use translates to a deterioration of crop quality for aphid development, resulting in lower aphid densities (Hasken & Poehling, 1995). The shift in crop types resulted in reduced aphid abundance as high-quality crops for aphids (cereals and alfalfa) were replaced by crops that support only poor aphid prey (oilseed rape).

The model simulates the habitat use and population dynamics of a stage-structured population of *C. septempunctata* in a heterogeneous landscape with a time step of one day. The landscape is represented as a grid of cells, where cells are assigned to habitat types. Four land use scenarios were analyzed reflecting the changes in land use in the Czech Republic: the situation before 1980 (scenario *1980*), a situation with 50% of the alfalfa acreage replaced by rape (scenario *alfalfa*), a situation with 15% of the cereal acreage replaced by rape (scenario *cereal*) and a situation with a 50% reduction of the carrying capacity of aphids in cereal and alfalfa induced by a reduction in fertilizer input (scenario *fertilizer use*). For the construction of maps for scenarios *alfalfa* and *cereal*, the appropriate amount of alfalfa or cereal acreage was reallocated by rape.

Results and discussion

Landscape composition affected the long-term population dynamics of *C. septempunctata*. In the scenario studies of the situation before the changes in land use (scenario *1980*), *C. septempunctata* populations reached equilibrium densities within 20 years. Ruzyne and Polabi, which were dominated by crops, supported approximately a two to three-fold higher population sizes than Milicin and Rana that contained relatively large proportions of forest and pasture. High acreages of the favourable alfalfa and cereal crops in Ruzyne and Polabi resulted in an intensive use of these habitats by *C. septempunctata*. In all four landscapes the vast majority of eggs were deposited in cereal crops. As this habitat supported similar aphid densities in all landscapes, immature survival of *C. septempunctata* did not differ between landscapes.

C. septempunctata population dynamics were also affected by land use. Reducing the alfalfa acreage with 50% and increasing the acreage of rape (scenario *alfalfa*) resulted in a

10.0% increase of the population size at the end of the simulation. This finding is remarkable since rape is a crop without aphid resources for *C. septempunctata*, and the accumulated aphid abundance in this scenario was less than in scenario *1980*. The population increase is caused by a switch in habitat use to cereal, prompted by the low quality of the rape habitat. Foraging in cereal crops enables ladybeetles to achieve high energy sequestration and reproduction because it provides ample aphid prey when ladybeetles have a high energy demand for reproduction, even though alfalfa is a superior habitat during the first 25 days of the growing season.

The importance of the cereal crops for *C. septempunctata* was further illustrated by a sharp drop (30.5%) in ladybeetle population density, caused by replacement of 15% of the acreage of cereal by rape. The decrease of the acreage of cereal resulted in a reduced energy sequestration and reproduction. The change in land use had the largest impact in Rana (-50.1%) and Milicin (-33.1%) because these landscapes had the lowest area of cereal, but also Ruzyne (-27.9%) and Polabi (-22.5%) were affected.

Halving the carrying capacity for aphids in cereal and alfalfa (scenario *fertilizer use*) affected the population dynamics of *C. septempunctata* in two ways. First, the lower prey availability reduced prey consumption and energy sequestration, resulting in a reduction in reproduction. Second, the reduced prey availability in cereal, which remained the major reproduction habitat, raised larval mortality levels due to starvation. The overall result was a 20-fold decline of the ladybeetle population.

In conclusion, the scenarios of land use changes indicated that reduced fertilizer input had the largest negative impact on *C. septempunctata* numbers of the scenario's studied, followed by the cereal acreage reduction scenario. It seems therefore plausible that the primary cause of the decline of ladybeetles in Czech landscapes is caused by a decline in aphids in cereal crops as a result of a reduction in fertilizer input.

Acknowledgements

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Functional biodiversity: A success story in vineyards of Northern Switzerland

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Abstract: Early attempts by agronomists of the Swiss Federal Research Station Wädenswil, Switzerland, to convert the traditional vineyard (a monoculture with open soil) to a complex agro-ecosystem with cover plants started in the late 1960s. The primary objective to protect vineyards on steep slopes against soil erosion was expanded in the 1980s to a strategy of habitat management with the aim to increase botanical and faunistic biodiversity as basic components of conservation biological control of key pests. The successful biological control of spidermites (*Panonychus ulmi, Tetranychus urticae*), of the green grape leafhopper (*Empoasca vitis*) and the natural regulation of *Drepanothrips reuteri,* and of the grape moth *Eupoecilia ambiguella* are discussed. Examples of habitat management as developed in Northern Switzerland are presented.

Key words: Viticulture, functional biodiversity, ecological infrastructures, conservation biological control, habitat management, key pests

Introduction

The history of habitat management in Swiss vineyards started in the late 1960s with experiments carried out by agronomists of the Swiss Federal Research Station at Wädenswil to protect vineyards located on steep slopes against soil erosion. They converted the traditional vineyard (a monoculture with open soil) into a more complex agro-ecosystem with cover plants. The primary objective to protect vineyards against soil erosion was expanded in the 1980s to a strategy of habitat management with the aim to increase botanical and faunistic biodiversity as basic components of conservation biological control of key pests.

The agro-ecosystem "vineyard" has a high ecological potential for various reasons:

- Perennial crop with a relatively high longevity;
- Pest complexity is lower than e.g. in fruit orchards;
- Key pests can often be controlled by indirect or soft direct plant protection methods (higher tolerance levels in grapes for vinification);
- The transformation of monocultures into more complex agro-ecosystems is possible by a green-cover strategy;
- Certain ecological infrastructures can be built directly into the crop area;
- Indirect plant protection measures (e.g. enhancing antagonist activity) are well developed and proven in practice.

Botanical diversity increases faunistic diversity

A detailed analysis of the flora and fauna of a terraced vineyard situated in Eastern Switzerland was carried out in 1984-86 and the insight gained in this study was verified in a similar survey conducted in 1987-1990 in 21 vineyards in Northern Switzerland (Remund et al., 1992; Boller, 2004a). With arthropod collections made monthly from April until September and annual botanical inventories the situation in weed-free plots of the vineyard was compared with data derived from that part of the vineyard exhibiting a botanically diversified permanent green cover. The insect collections clearly show the paramount importance of a high botanical diversity (species richness) for vineyard fauna complexity. It is estimated that in many vineyards some 2000-3000 different arthropod species and close to 100 different plant species exist as important components of the agro-ecosystem "vineyard". The vineyards investigated are characterised by a relatively small size, steep but terraced slopes and rich ecological infrastructures in the neighbourhood (hedges, forest, poor grassland). The relationship between the number of (flowering) plant species and the number of faunistic groups (taxa) observed in 1990 in the 21 investigated vineyards located in Northern Switzerland is presented in Figure 1.

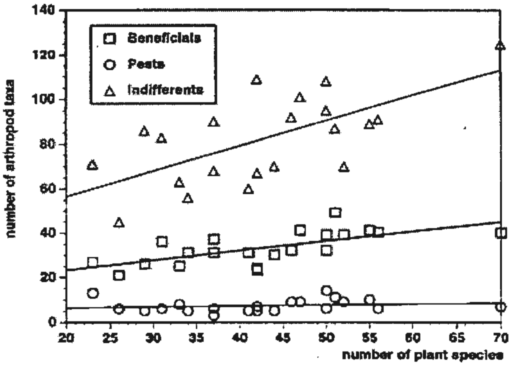

Figure 1. Relation between botanical species richness and number of arthropod taxa observed on 21 vineyards of Northern Switzerland in 1990. Points: individual vineyards; circles: pest species; triangles: indifferent plant feeders; squares: beneficial entomophagous species.

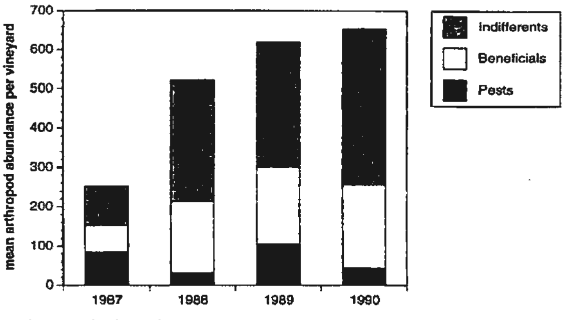

Figure 2. Average arthropod abundance of 21 vineyards in Northern Switzerland.

With increasing botanical diversity we observe a strong increase in indifferent plant feeders, followed by a somewhat smaller but still significant increase of the beneficial antagonists whereas the number of pest species remains constantly low (Boller et al., 1997; Boller, 2004a). Almost spectacular is the observed development of the fauna in the same vineyards, where the alternating mowing regime was introduced in 1987 and where flora and fauna were analysed twice per year (Fig. 2).

Typhlodromus pyri: Biological control of spidermites and other small arthropods

Although present as potential pests in Swiss vineyards, spidermites (*Panonychus ulmi, Tetranychus urticae*) and other small arthropds (such as *Drepanothrips reuteri*) are perfectly controlled since the mid 1970s by the phytoseiid mite *Typhlodromus pyri*. Between 1985 and 1990 a vineyard area of 45 ha was established as predatory mite reservoir by transferring the key antagonist from a research vineyard in Eastern Switzerland to the lake of Zürich area and from there to all viticultural cantons of Northern Switzerland. Investigations showed clearly that *T. pyri* can survive on pollen in the absence of animal prey and hence can be enhanced by alternating mowing (Wiedmer & Boller, 1990). Investigations in hedges showed that brambles (*Rubus fruticosus*), dog wood (*Cornus sanguinea*), hazelnuts (*Corylus avellana*) and fly honeysuckle (*Lonicera xylosteum*) are important sources of this predatory mite (Boller et al., 1988).

The green leafhopper Empoasca vitis controlled by its egg parasitoid Anagrus atomus

Investigations carried out in Northern Switzerland showed the importance of wild roses and brambles in the hedges for the build-up of the egg parasitoid *Anagrus atomus* on indifferent small leafhopper species. The population density of the green leafhopper *Empoasca vitis* is significantly reduced in plots with green cover and its density is further pushed below economic threshold levels by its parasitoid *Anagrus atomus*. The survival of the parasitoid, however, depends on a permanent flower supply in the green cover providing the vital provision of nectar, pollen and honey-dew. A high botanical diversity with suitable perennial broad-leaf plants and alternating mowing are important components of this successful conservation biological control (Remund & Boller, 1995, 1996; Boller, 2004c).

Trichogramma: importance not verified in Northern Switzerland

Trichogramma species are often reported as important antagonists of the grape berry moth *Eupoecilia ambiguella* and longterm population assessments of the pest in a botanically diversified vineyard indicate the suppression of the pest population by parasitoids. However, a direct impact of *Trichogramma* in Northern Switzerland could not be confirmed as the parasitisation rates were not always consistent and the *Trichogramma* densities, as monitored by yellow sticky traps, were in most cases very low (Boller, 2001).

Habitat management improved

The successful and area-wide application of a permanent green cover and of alternating mowing in Northern Switzerland has substantially increased the quality and effectiveness of this ecological infrastructure placed directly into the cropping area. However, species-rich plant communities have a natural tendency to develop into more trivial grass-dominated stands after approx. four years (succession). Practical recommendations have been worked out in Switzerland to maintain the desirable botanical diversity level by spading every 2nd alleyway every 4th year. By staggering this procedure the green cover is eventually composed of four different age groups of cover plants that provide, as a whole, an optimum of ecological quality (Gut, 1997; Boller, 2004b).

Reaction of the farmers

The establishment of green covers in the vineyards as protection against erosion was at the beginning rather slow as the idea was new and in contradiction to the old traditions. However, this situation changed in the mid 1980s when the basic elements of Integrated Production in viticulture – including green cover plants and habitat management – were developed in close collaboration between applied research and farmers. The practical experience with alternating mowing at the farm level was supported by botanical and faunistic surveys conducted by the research team of the Wädenswil research station and demonstrated, on site, the impact of habitat management. A survey made in 1993 (Boller et al., 1994) showed that the ecological bonus-malus system developed by the Wädenswil team ("Wädenswil model") had a stimulating effect as more than 90% of the vineyards in Northern Switzerland showed green cover with adequate management procedures. Many farmers participated in botanical and faunistic field training courses.

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Functional biodiversity at the farm level as seen by IOBC

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Abstract: Functional biodiversity at the farm level has found a prominent place in normative IOBC documents published since the early 1990s. During the practical implementation of Integrated Production programs by IOBC endorsed growers' organisations it became obvious that adequate basic and practical information on ecological infrastructures and on their function in conservation biological control was often lacking. Therefore, an IOBC toolbox was established in 2001 as attempt to bridge the most important gaps. The present contents of the toolbox and open questions are discussed. There is need to review and compile established concepts, methods and tools existing in many countries, which are often unknown or difficult to read. Certain existing tools would merit being developed further and made available to the interested partners.

Key words: Functional biodiversity, ecological infrastructures, conservation biological control, tools, IOBC guidelines

Introduction

Functional biodiversity at the farm level has found a prominent place in normative IOBC documents published since the early 1990s: in the basic document on Integrated Production principles published in 1993, 1999 and 2004, and in chapter 3 of all crop specific Technical Guidelines III. The active support of biological diversity as postulated by the principle no. 9 of the basic document on Integrated Production (IOBC, 2004) reads as follows:

> *9) BIOLOGICAL DIVERSITY MUST BE SUPPORTED*
> *Biological diversity includes diversity at the genetic, species and ecosystem level. It is the backbone of ecosystem stability, natural regulation factors and landscape quality. Replacement of pesticides by factors of natural regulation cannot sufficiently be achieved without adequate biological diversity. Stable agro-ecosystems in which flora and fauna are diversified provide important ecological services to the farmer covered by the term "Functional Biodiversity".*

Chapter 2 of Technical Guideline II provides the frame for the biodiversity chapters of all crop specific Technical Guidelines III as follows:

> ***2.0 Biological Diversity and Landscape***
> *The biological diversity at all 3 levels (genetic, species, ecosystem) must be increased actively. It is one of the major natural resources of the farm to minimise pesticide input.*
>
> ***2.1 Ecological infrastructures*** *(ecological compensation areas)*
> *These must cover at least 5 % of the* ***entire farm surface*** *(excluding forest). Existing ecological infrastructures on the farms must be preserved. Headland attractants (flowering field margins), should be established as reservoirs of pest antagonists. Areas of linear elements (e.g. flowering border strips, hedges, ditches, stone walls), and non-linear elements (e.g. groups of trees, ponds etc.), being present or to be planned on the farm should be combined in such a manner as to*

obtain spatial and temporal continuity. This continuity is a prerequisite for the enhancement of faunistic diversity and for the maintenance of a diverse landscape. (Practical examples on the evaluation of ecological quality, their functions, establishment and maintenance are given in the Tool Box). The surface of ecological infrastructures with low production intensity and without pesticide/fertilizer input should eventually increase to 10%. The 5% rule need not necessarily be applied to an individual farm in areas with predominantly small farms, with highly scattered properties, and where a surface of 5% or more of a common and homogeneous agro-climatic unit (e.g. municipal district), has been set aside as ecological infrastructures by official and well documented regional programs. In this case, it has to be shown that the ecological infrastructure areas are well distributed in time and space in the municipal area, thus providing a guaranteed continuity.

2.2 List of options

*IP guidelines must provide a **list of at least 5 ecological options** for the active enhancement of biological diversity. At least 2 appropriate options have to be selected as "must" by the individual farmer. Examples of such option lists are given in the Tool Box.*

2.3 Field size

*The **lateral** dimension of an individual field should be considered as an important element in functional biodiversity, to provide ecological reservoirs and to secure connectivity with adjacent ecological infrastructures (see Tool Box).*

2.4 Buffer zones

between crop areas and sensitive off-crop areas, (such as surface waters, springs, important ecological infrastructures, heavily travelled roads), must respect legal regulations. If no official regulation exists buffer zones must be at least 3 m wide, but preferably wider.

Other relevant aspects are addressed by chapter 8 of the Guideline II (8.0 Integrated Plant Protection), especially in chapters 8.1 (Principles of IPP) and chapter 8.3 (Green and yellow lists of plant protection measures). IOBC endorsed organisations have to establish

- a restrictive list of key pests, diseases and weeds;
- a list of the most important site specific natural antagonists;
- a list of preventive and highly selected direct control measures to be used in the IP program ("Green list"), and
- a list of pesticides to be used with restrictions ("Yellow list").

Identified problems and first steps to solve them

During the practical implementation of Integrated Production programs by IOBC endorsed growers' organisations in the late 1990s, the Commission was facing certain problems. The organisations had no problems to identify and list the key pests and diseases and made fast progress in identifying some 5% of ecological compensation areas. More problematic was the identification and listing of the site-specific key antagonists. The most serious obstacle was the fact that adequate basic and practical information on ecological infrastructures, on their function in conservation biological control and on their adequate management was often lacking.

Biodiversity becomes an IOBCwprs topic in the late 1990s. An analysis of the IOBCwprs bulletins revealed that the activities reported by the working groups contained valuable information about the occurrence and even bionomics of important antagonists but very little information about their habitats and about respective habitat management. This situation was brought in 1999 to the attention of IOBCwprs Council with the proposal to sensibilise the relevant working groups in this respect. With success. The viticulture group started to address functional biodiversity topics during their biannual meetings and the orchard group invited speakers on biodiversity issues to their 2001 symposium on Integrated Fruit Production held at Lerida/Spain. And last, but not least, the General Assembly of 2001 (Ascona) accepted the proposal to establish a new working group on "Landscape Management for Functional Biodiversity". The proceedings of the first meeting taking place in 2003 at Bologna offer an excellent international review of the state of the art in this emerging research field (Rossing et al., 2003).

IOBC Toolbox on internet. In 2001, the Commission established und published for the first time on internet its IOBC toolbox (www.iobc.ch). It has continued to fill it with practical and field-proven tools to assist growers' IP organisations in their development and application of IP programs according to IOBC standards. The preparation and publication of "Ecological Infrastructures: Ideabook on Functional Biodiversity at the Farm Level" (Boller et al., 2004) and the new concept of the "Green list of Plant Protection Measures" (IOBC, 2005) are two tools directly related to the biodiversiy issue.

More and better tools needed

The preparation and publication of the English-German version of the "Ideabook" mentioned above was an emergency project of the Commission to satisfy immediate needs. The fact that the book has found world-wide interest and is being translated into additional languages should not obscure that this IOBC document is not a practical manual nor a complete review of existing methodologies. The book is a first (and incomplete) compilation of ideas focussing on and collected in the temperate zones of Europe. During our search for practical tools we found, often by serendipity, a number of interesting approaches on: how to measure the ecological quality of ecological infrastructures, how to establish, improve and manage ecolocical infrastructures, how to connect individual infrastructures at the landscape level etc. Many of the excellent documents and technical leaflets listed in chapter 4 and 5.1 of the "Ideabook" are focussing on geographically limited situations and provide interesting solutions that can, however, not be extrapolated and transported to more distant regions (or continents) without adequate professional adaptations. An attempt to this end is the compilation of a tentative IOBC list of options to enhance biodiversity at the farm level published in chapter 1.7 of the "Ideabook".

Here I see a real challenge for IOBC and especially for this particular IOBCwprs Working Group on "Landscape Management for Functional Biodiversity". Respective activities could

- expand the geopgraphic scale of collecting and compiling existing field-tested methods;
- establish a priority list of important tools still lacking but needed for enhancing functional biodiversity at the farm and landscape level;
- develop, in close collaboration with the authors of the original documents, a number of existing and highly promissing local/regional approaches into more general, robust and easy tools whilst respecting sound scientific principles.

The addressees of such future tools should be our ultimate partners: the interested, motivated, well trained and/or untrained farmer families implementing our recommendations on their farms.

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Landscape management as a «sustainable agriculture» tool: the role of local administration and research in the Emilia-Romagna region (northern Italy)

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Abstract: Since the seventies, the Emilia-Romagna Region (northern Italy) has promoted sustainable agriculture through regional initiatives and large scale application of both structural and rural development policies. In this paper the environmental interventions are reviewed, including an evaluation of the relative efficacy. Due to the growing interest to know and investigate functional biodiversity, suitable biological indicators must be selected in order to evaluate the quality of ecological interventions in rural landscapes. Biodiversity data on bird, insect and plant communities within typical intensive rural landscape areas within the Emilia-Romagna region are provided and discussed.

Key words: agro-environmental measures, landscape management, biodiversity conservation

The agriculture of Emilia-Romagna region and the initiatives to promote sustainable agriculture

The Emilia-Romagna Region (northern Italy, or Po' Valley) is one of the most important agricultural areas in Europe. The total agro-industrial sector produces a gross output of 10,500 MEuro per year and a value added of 2,300 MEuro, which is more than 1/6 of the total national agro-industrial production. Intensive agriculture of the area contributed to the environmental pollution of Po River plain with nitrates (surface and ground water) and pesticides (mainly in ground water and sometimes in the form of residues on products). In order to apply the methods of integrated pest management and integrated production, since the 1980's, the regional Government has promoted field research and organised a specific Regional Advisory Service for the adoption of integrated production methods, including a quality trade-mark («QC», «*Qualità controllata*») to promote the produce of IPM farms has been set up.

Agro-environmental measures and rural landscape interventions

The agro-environmental actions of the Regional programs included actions related to agronomy techniques and production (i.e. IPM and organic agriculture), and actions related to environmental techniques *sensu strictu.* In particular, Emilia-Romagna Region has promoted biodiversity conservation interventions through the following measures: conservation and maintenance of natural habitats; and reduction of arable crops in order to create environments for wild fauna and flora. The agro-environmental interventions, which shared the same objectives as the EU directives «Habitat» and «Birds», were applied on about 9000 hectares within the «Rural Development Planning» (of which 4000 in the «Natura 2000» net), in conformity with the agro-environmental schemes of EEC Regulation 2078/92 and EC Regulation 1257/99. The total supports from agro-environmental schemes are listed in Table 1.

Table 1. Supports from agro-environmental schemes within the Emilia-Romagna region, including Regulation (EEC) 2078/92 (1995-1999) and Regulation (EC) 1257/99 (2000-2005).

Agro-environmental schemes	Total supports (MEuro)	No of farms	Hectares
2078/92	199.1	14,847	233,000
1257/99	126.6	6,100	118,000

Agro-environmental interventions were supported and applied with priority in the flat areas characterised by consistent habitat fragmentation and they achieved the following results: i) conservation of natural habitats (hedges, wood patches, marshes) on at least 5% of the farm area, to improve rural landscape quality and biodiversity conservation; ii) restoring and re-naturalisation of arable lands, creating habitats suitable for fauna and flora, like wet-land habitats and wood-land patches. These interventions contributed to the conservation and to the reproduction of aquatic bird communities, as bird monitoring employed since 1996 has shown.

Since 2005, financial support was reinforced by the «New European Common Agricultural Policy», under the «cross-compliance» principle, which should ensure the sustainability measure within the EU. Emilia-Romagna has applied the «cross-compliance» principle within EC 1783/03 rule, integrating the national decrees of Ministry of Rural and Forestall Policy by means of local rules. These regional rules have integrated a specific rule (4.2) on «Management of areas retired from crop production», which provides some derogations like: i) the maintenance of vegetal cover mixture for wild fauna until the end of February; ii) interventions for the restoring of habitats and biotopes. Regarding this last aspect, Emilia-Romagna was the only region in Italy to propose, by a specific deliberation, the «Applications for rural farms involved in habitat and biotopes restoring». The «wet-meadow» habitat was selected as a primary biotope to restore within flat areas of the «Natura 2000» net. Moreover, Emilia-Romagna region regulated the management of the wet-meadows, by allowing mowing only during the August-October period, to avoid negative impacts on the reproduction of protected bird species.

Evaluation of the efficacy of the agro-environmental interventions

In 2005 the Emilia-Romagna region promoted an intermediate report aimed at the evaluation of the efficacy of the interventions carried out by means of the agro-environmental measures (Emilia-Romagna Region Report, 2006). The evaluation of the efficacy of agro-environmental measures was carried out by means of a number of indicators (Table 2). The benefit due to soil erosion reduction was calculated for the total area of orchard farms: mulching reduced the soil losses by about 180,000 Mg/year in comparison with conventional farms, corresponding to an estimated efficacy of about 9%. The reduction of nitrogen and phosphate inputs led to a general improvement of the water quality. It is interesting to note that the efficacy of the pesticide input reduction was calculated on the basis of an index weighed on the chronic toxicity: the index is higher when the pesticide rates and toxicity are greater and the greater reduction was obtained in the "hill farms". Therefore, this indicator takes into account the social benefits due to lesser use of pesticides. The efficacy of the agro-environmental measures on the biodiversity and habitat conservation was in general positive but the efficacy was higher in organic farms and in farms characterised by lower pesticide inputs. The protection and conservation of natural habitats and ecological infrastructures led to a strong increase in the abundances of some bird species and rare plant species.

Table 2. List of the indicators used to assess the efficacy of the agro-environmental measures. Quantitative efficacy measures are obtained by comparing areas involved in the agro-environmental measures with those on "conventional" farms. Biodiversity and habitat conservation are expressed in a qualitative intensity of the efficacy.

Indicators	Estimated efficacy	Comments
Soil erosion reduction	9 %	Benefit evaluated in mulch-orchard farms
Water pollutants input reduction (total)	48 %	For nitrogen
	58 %	For phosphor
Water pollutants input reduction (per area unit)	3 %	For nitrogen
	6 %	For phosphor
Pesticide input reduction	10 %	For the total of farms
	70 %	For hill farms
Biodiversity and habitat conservation	+	«Average» efficacy
	++	Efficacy in organic farms
	+++	Efficacy related to the conservation of rare and target species

The role of research in the evaluation of landscape interventions: how to assess rural landscape quality in a macro-scale context

A multi-disciplinary project, called «Compatibility between agriculture and wild fauna within intensive agroecosystems» has been funded by the Italian Ministry of Agricultural and Forestry. The aims of the project - coordinated by Istituto Nazionale per la Fauna Selvatica, Ozzano, Italy - were to evaluate biodiversity in a typical intensive rural landscape of the low-land area within the Emilia-Romagna region and to give practical recommendations on management of ecological compensation areas. A specific sub-project aimed to analyse the relationship between bird communities and field-margins features. Five large study areas (2.200 to 15.300 ha) were selected from 50 digital photographs by means of GIS (Fig. 1). Results showed that bird community parameters were significantly affected by vegetation structure and floral richness gradients, while bird abundance was correlated with land use. Another sub-project aimed to assess the insect and plant diversity in nine sites within an area (Fig. 1) in order to make an inventory of biodiversity and to evaluate the quality of rural environment. Floral richness of the sites ranged from 35 to 84 species, for a total of 180 plant species. Floral richness was not dependent on vegetation structure and complexity of the area around the site, but it was related with the percentage of weed cover and with vegetation types (Table 3). In order to assess insect biodiversity, a composite monitoring system that involves different sampling methods was employed. The role of different functional insect bioindicators was compared, with the aim to contribute to the compilation of a data bank for environmental assessment. Syrphid species (n=55) were correlated with Symphyta species (n=41). Butterfly species (n=39) and abundances were positively correlated with the floral richness and negatively influenced by the complexity of vegetation structure and by the percentage of tree cover; moreover butterfly abundance was positively correlated with the percentage of weed cover. In the research, rare plants and insects species for Italian rural landscape were recorded. Syrphid flies (Diptera) were analysed by means of «*Syrph the Net*», a standard method initially developed for Atlantic Europe and then extended to Central

Europe (Speight et al., 2005), in order to obtain information on the quality of rural landscape. By means of this approach it is possible to calculate a «biodiversity maintenance function» of a site, that is, an index based on differences between the occurrences of observed and expected species. If the pool of species predicted to occur in a particular habitat is observed in a target site, then the biodiversity maintenance function is performing at maximum efficiency in that habitat on that site. From analysis of data by means of «*Syrph the Net*», it can be seen that for six sites the maintenance biodiversity function ranged between 50 and 74%, showing good quality of the habitats *sensu* Speight et al. (2005). The first results obtained in this study by means of «*Syrph the Net*» are promising and the potential application of the method is discussed.

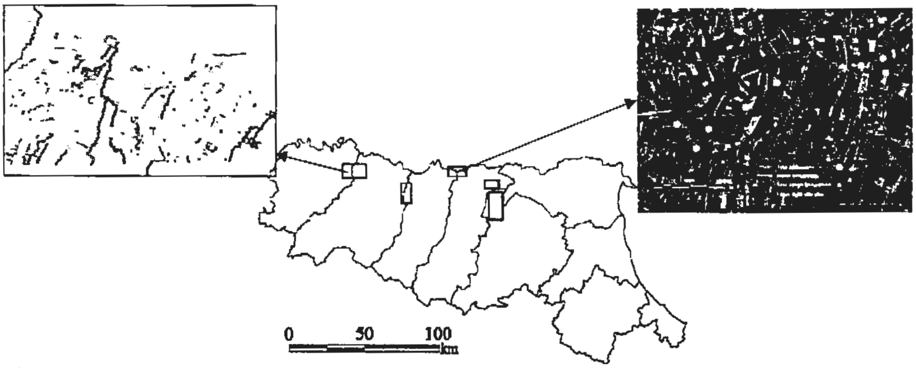

Figure 1. The square on the top-left reports an example of the field margins studied within the bird biodiversity sub-projects. The square on the top-right reports the area investigated within the insect-plant biodiversity project, including the nine points monitored.

Table 3. Correlation matrix between the number of insect species and vegetation features. In the table are listed the Spearman correlation coefficients (*: P<0.05; **: P<0.01).
(°) ICSV: Index of vegetation structural complexity.

	# Symphyta species	# Syrphidae species	# Carabidae species	# butterflies species	# plant species	ICSV	% trees cover	% shrub cover	% weed cover
# Symphyta species	1	**0.75 ***	-0.003	0.09	-0.09	0.52	0.45	0.56	-0.44
# Syrphidae species	**0.75***	1	-0.11	-0.008	-0.35	0.3	0.22	0.51	-0.29
# Carabidae species	-0.03	-0.11	1	0.34	0.3	-0.24	-0.15	-0.50	0.26
# butterflies species	0.09	-0.008	0.34	1	**0.71***	**-0.66***	**-0.70***	-0.18	0.56
# plant species	-0.09	-0.35	0.3	**0.71***	1	0.44	7	-0.61	**0.73***
ICSV (°)	0.52	0.3	-0.24	**-0.66***	-0.44	1	**0.96***	0.52	**-0.76***
% trees cover	0.45	0.22	-0.15	**-0.70***	-0.55	**0.96*****	1	0.54	**-0.86****
% shrub cover	0.56	0.51	-0.5	-0.18	-0.61	0.52	0.54	1	-0.80**
% weed cover	-0.44	-0.29	0.26	0.56	**0.73***	**- 0.76***	**-0.86****	**-0.80****	1

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Landscape effects on the abundance of Lepidopteran pests in Brussels sprouts

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Abstract: Larval densities of *Pieris rapae* and *Plutella xylostella* in Brussels sprouts were compared at 32 organic farms in different landscape settings. Both herbivorous species, mostly restricted to genera of Cruciferous plant species, were recorded by individual plant observations during the growing season to analyse and compare their population dynamics in relation to the surrounding landscape.

Multiple regressions of the data showed the importance of non-crop habitats such as hedgerows and woody habitats in reducing the abundance of *P. rapae* larvae and similarly, the importance of non-crop habitats as line features and woody habitats in reducing the abundance of *P. xylostella* larvae. Abundance of larvae from both species was positively correlated with the horticultural area, while the abundance of *P. xylostella* larvae was correlated with solitary trees. The results suggest that structurally complex landscapes with networks of hedgerows and woodlots and a limited horticultural area may have sufficient potential for pest control.

Key words: landscape structure, butterflies, non-crop habitat, *Pieris rapae, Plutella xylostella*

Introduction

Landscapes in the Netherlands have changed during the last 50 years due to the intensification of agriculture and changes in land use. Hedgerow networks and woodlots in the agricultural landscape have been under significant pressure in many parts of the country. Landscape structure and habitat fragmentation influence the ecology of field crop pests and their natural enemies (Ekbom et al., 2000). Depending on the type (walking, passive, or active flight), intensity of movement and host plant range, insect species will interact with the spatio-temporal structure of the landscape. Non-crop habitats may serve as dispersal corridors, or may act as a barrier therefore reducing dispersal of individuals between fields. Woodlots, hedgerows (Bianchi et al., 2005) and solitary trees may enhance the occurrence of natural enemies and lead to an increase in predation or parasitization of pests (den Belder et al., 2006).

During a period of three years, pests and natural enemies in Brussels sprouts (*Brassica oleracea* L. var. gemmifera) were monitored. This paper focusses on *P. rapae* (Lepidoptera: Pieridae) and *P. xylostella* (Lepidoptera: Plutellidae). *P. rapae*, a species with a high degree of mobility tends to follow linear flight paths until adults find themselves in the vicinity of hosts (Fahrig & Paloheimo, 1988). They oviposit on cruciferous vegetables. Larvae tend to stay on their natal plant and consume large portions of leaves. *P. xylostella* has become one of the most destructive species in cruciferous crops in the Netherlands. This species is capable of migrating over long distances, but within crop movement of adults is limited.

This study aims to determine the density of larvae of *P. rapae* and *P. xylostella* in Brussels sprout in landscapes with varying lengths of linear non-crop habitats, areas of non-crop habitats and agricultural and horticultural areas.

Material and methods

Study area: In the summers of 2001 and 2002, 22 organic farms with Brussels sprouts were investigated in 11 provinces in the Netherlands. They were located in landscapes with varying areas of natural habitats, pasture, agriculture and horticulture and varying lengths of linear features. The fields varied in size from 0.2 to 5.1 ha.
Sampling: Lepidopteran populations in Brussels sprout fields were monitored four times during the growing season. All fields were visited within a period of 5 days in July, August, September and October. Plants were chosen along four 50-meter transects in four adjacent sections of each field. From each plot, 16 Brussels sprout plants were examined for the number of larvae of *P. rapae* and *P. xyllostella*.
Measures of landscape structure: Landscapes surrounding the Brussels sprout fields were characterized in circles with 0.3, 1, 2 and 10 km Ø using a combination of the GIS frameworks Top10 (Dutch National Mapping Agency) and LGN4 databases. The databases included the length of hedges, tree lines, length of forest edges, channels, dikes, road verges, field edges as well as the area of forest and other natural habitats, pasture, agriculture, horticulture, orchards, water, urban areas, roads and solitary trees. Fragmentation of woodlots and production fields were also used as predictor variables in the stepwise multiple regressions (den Belder et al., 2002). In total 20 landscape variables were recorded. Landscape maps were completed with farmers' interviews.
Data analysis: Statistical analyses were performed with the ^{e}log transformation of cumulative number of larvae (we distinguished small and large larvae according to their size) as separate response variables. The RSELECT procedure in the Genstat 6 programme was used in model selection for stepwise multiple regression modelling. F tests were used to determine the significance of predictor variables in regression models with $p = 0.10$ for inclusion of a predictor in a model. Best subsets of predictor variables were selected based on Mallows' Cp-values close to the number of predictor variables in the fitted model, the number of p as small as possible, and the largest adjusted R^2.

Results

Analysis of the predictor variables showed different patterns for both species. The number of *P. rapae* larvae varied significantly in landscapes with dense from that in open hedgerow networks (length varied between 0 and 12.5 km at a scale of 2 km Ø, average was 1.9 km, Table 1). At all four spatial scales, hedges had a negative effect on the number of *P. rapae* larvae (Table 2A). The cumulative number of *P. rapae* larvae was also significantly negatively related to forest habitats (all larvae) and to other natural habitats (small larvae, at 2 km Ø). The multivariate analysis further indicated that the distance between Brassica fields was significantly negatively related to small *P. rapae* larvae, and the area of horticulture was positively related to large *P. rapae* larvae (Table 2A). Similar to *P. rapae* larvae, small *P. xylostella* larvae were significantly negatively affected by the length of the hedgerows (Table 2B). Larvae of *P. xylostella* (small, large and all) were positively related to the number of solitary trees within a 2 km diameter (Table 2B, number of solitary trees varied between 0 and 106, this number was not significantly correlated with other landscape elements). Similar to *P. rapae* (large larvae), the number of *P. xylostella* larvae (small and all larvae) increased with an increase in horticultural areas. The length of forest edges had a negative effect on the number of larvae.

Table 1. Landscape variables for 22 Brussels sprout fields within 2 km Ø.

Variable	Mean	Range
Percentage of grassland/pasture	37.4	5.4 – 80.0
Percentage of agricultural land	29.4	3.4 – 78.4
Percentage of horticultural land	11.0	0.0 – 37.4
Percentage of woodlots	9.3	0.1 – 54.7
Percentage of natural habitats (without trees)	0.3	0.0 – 14.3
Percentage wetlands/water	2.0	0.0 – 8.6
Fragmentation: boundary/surface production land (km^{-1})	17.0	11.4 – 33.7
Fragmentation: boundary/surface woodlots (km^{-1})	174.4	11.3 – 597.5

Table 2A and B. Analysis of variance. The response variables are ^{e}log number of larvae of *P. rapae* and *P. xylostella* measured in organic Brussels sprouts fields within 22 landscapes.

2A: *P. rapae*: small larvae 2 km Ø (Adj. $R^2 = 45.6$)					
Source	df	SS	F value	P > F	Coefficient
Constant					2.460
Distance between *Brassica* fields	1	1.97	5.11	0.036	-0.0007
Length hedgerows	1	3.46	8.97	0.008	-0.1305
Natural habitats	1	3.46	8.97	0.008	-0.1306
Residual	18	6.94			
Total	21	14.86			
P. rapae: large larvae 2 km Ø (Adj. $R^2 = 37.2$)					
Constant					0.344
Area of horticulture	1	4.60	7.52	0.013	0.0147
Length hedgerows	1	3.36	5.49	0.031	-0.1367
Length canals	1	5.48	8.95	0.008	-0.0477
Residual	18	11.02			
Total	21	20.47			
P. rapae: all larvae all Ø (Adj. $R^2 = 46.8$)					
Constant					2.834
Forest 10 km diameter	1	5.51	15.25	<0.001	-0.495
Length hedgerows 2 km diameter	1	2.47	6.82	0.017	-0.110
Residual	19	6.87			
Total	21	14.28			

2B: *P. xylostella*: small larvae 2 km Ø (Adj. $R^2 = 65.1$)					
Source	df	SS	F value	P > F	Coefficient
Constant					0.0010
Area of horticulture	1	6.02	9.62	0.006	0.0016
Solitary trees	1	15.88	25.40	<0.001	0.0263
Fragmentation of forest	1	9.17	14.65	0.001	0.0041
Residual	18	11.26			
Total	21	37.69			
P. xylostella: large larvae 2 km Ø (Adj. $R^2 = 45.5$)					
Constant					1.441
Length of hedgerows	1	2.06	4.08	0.058	-0.0099
Solitary trees	1	4.51	8.97	0.008	0.0142
Length of forest edges	1	6.23	12.37	0.002	-0.0599
Residual	18	9.06			
Total	21	19.41			
P. xylostella: all larvae all Ø (Adj. $R^2 = 44.2$)					
Constant					1.014
Area of horticulture 0.5 km radius	1	8.00	8.76	0.008	0.0545
Solitary trees 0.5 km radius	1	13.82	15.14	<0.001	0.0816
Residual	19	17.35			
Total	21	34.35			

Predictor variables, see section Material and Methods.

Discussion

In this study there was a clear negative effect of the surrounding landscape on the abundance of larvae of two individual butterfly species in Brussels sprouts. The results of this study support the findings in other studies that the surrounding landscape has a negative effect on the abundance of *P. rapae*. Bergman et al. (2004) found that the occurrence of *P. rapae* butterflies decreased with increasing amounts of woodland and grassland. Hedgerows may slow down butterfly movement through the landscape (Dover, 1997) and distract dispersing individuals so that they never reach new suitable habitat patches. Linear non-crop habitats may fulfil similar ecological functions as woody habitats and stimulate predation (Bianchi et al., 2005) or parasitation (Marino & Landis, 2002). In this study *P. xylostella* larvae abundance was positively correlated with the number of solitary trees at multiple scales. This is in contrast with the lower number of cabbage aphids and the higher percentage of parasitized aphids we found in the same fields (den Belder et al., 2006). Information on effects of solitary trees on Lepidopteran pests is scarce. Solitary trees may possibly have a direct influence on colonization (Marino & Landis, 2002). It may be possible that solitary trees were correlated with landscape features or other management practices we did not identify. Abundance of both species seemed to be positively correlated with the horticulture area. This study shows that an increase of Brussels sprouts results in a higher number of pest species than the resource concentration theory describes. Also intensively used production areas are likely to limit the effectiveness of natural enemies through management regimes imposed on these systems (Landis et al., 2000). This study suggests that non-crop habitats like woodlots and hedgerows are important for the control of larvae of both *P. rapae* and *P. xylostella*. The results suggest that structurally complex landscapes with dense networks of hedgerows and woodlots and a limited horticultural area may have potential for pest control.

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Success stories in landscape management for functional biodiversity: an assessment from 5 west-European countries

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Abstract: Within IOBC, a small scale inventory was made to collect success stories in landscape management for functional biodiversity. Five projects from different European countries were analysed to define the indicators in the people, planet and profit domains being seen as important for success. Projects primarily related to functional biodiversity focused on indicators relevant for farmers, with direct pest/natural enemies assessments and pest management costs and savings considerations at the field and farm level. Projects with a broader emphasis on biological conservation in the countryside often took into account functional biodiversity aspects, but related mostly to a wider range of actors and at a landscape level. Since landscape management for conservation reasons is quite successful it is argued to bring functional biodiversity in line with biodiversity conservation strategies.

Key words: functional biodiversity projects, pest control, sustainable agriculture, biodiversity conservation, criteria for success

Introduction

Agriculture can be regarded as the most important determinant of the landscapes of the European countryside. Local physical conditions and human traditions resulted in a variety of landscapes and created a wide range of conditions for biodiversity. Only plant and animal species adapted to dynamics of agriculture can survive or will even be enhanced. However, since agriculture production has been boosted for world markets, using high quantities of inputs, we have a de-linking of food production and biodiversity. The intensive land use had a dramatic impact on landscape quality and biodiversity. Today, in countries like the Netherlands only 2-3% of the area of an arable farm can be regarded as a semi-natural habitat, such as ditches and hedgerows (Manhoudt & de Snoo, 2003).

Over the last decades, many attempts have been made to enhance the quantity and quality of semi-natural elements left in the countryside. Most mentioned reasons for the improvement of such habitats are: 1) to contribute to nature conservation (food, shelter, migration habitats of plants and animals, including rare species); 2) to improve environmental quality (buffer strips to prevent pesticides and nutrients contamination) and 3) to promote the aesthetic values of the countryside. Finally, such landscape features can also enhance functional biodiversity for farmers, for example related to pest control.

Over the years much progress has been made with respect to the above three motivations for semi-natural habitat management: within the scientific community applied and fundamental research is being carried out and debates are going on about the effectiveness of the measures developed and the implementation of strategies. Within society EU and national regulations such as agri-environmental schemes have been implemented, farmers collectives established and a wide range of actors is involved. Here habitat management is really in the core business of sustainable rural development. However, related to the topic of landscape management and functional biodiversity the progress seems to be much more limited. Therefore, in this contribution we would like to identify current success stories of landscape management for biological control.

Approach

Call for success stories

An inventory was made among senior scientists of the Working Group Landscape Management for Functional Biodiversity to collect examples of successful projects regarding landscape management for functional biodiversity within Europe. Besides the collection and description of the projects the following questions were of interest: 1) what means success for the projects? 2) how can this success be measured? and 3) what are the critical factors that made the project into a success?.

We received success stories from 5 European countries. We then specifically addressed representatives from other European countries for further examples, but did not obtain results that matched the criteria of both technical and social success. Written accounts of the success stories were provided by the authors, either in the 4-page format of the present IOBC-wprs Bulletin (Boller, 2006; Burgio et al., 2006; Mante & Gerowitt, 2006; Van Alebeek et al., 2006, this volume), or previously published material (Powell et al., 2004; Jacot & Bosshard, 2005). A workshop was convened on 22 March 2006 at Leiden University to present, analyze and compare the accounts. All authors of this paper attended the workshop.

Analysis

The success stories were analyzed from two angles. The first focused on how to define and measure success. Here the success stories were reviewed in terms of the three domains of sustainable development: people, planet and profit. It was hypothesised that the planet dimension would be well covered, although indicators might vary slightly; the profit dimension would have received some attention, but clearly less than the planet dimension; and the people dimension would be virtually non-existent. The second angle addressed spatial scale. At which scales were the different success stories evaluated: field, farm, region? Can we claim a contribution to science from our work and generalize local experiences to other locations and scales?

Results and discussion

Success indicators

From the analysis of the different case studies it became clear that three of the projects have a direct focus on the enhancement of functional biodiversity (United Kingdom, The Netherlands and Switzerland: mainly the vineyard success story *cf.* Boller, 2006). The projects of Italy and Germany and the Swiss EFM project (*cf.* Jacot & Bosshard, 2005) primarily focus on biological conservation in the countryside and, in the case of Italy, also on reduction of agricultural inputs. In Table 1 the results of the self-evaluation by the involved researchers is presented. In the *people domain* the three projects focusing on functional biodiversity used acceptance of the technology by farmers and advisors as criteria for success. The German and Italian projects with a focus on biodiversity conservation emphasized the number of farmer and stakeholder groups involved. Only in the projects in Germany, Switzerland and the United Kingdom were actors other than farmers or the general public seen as important targets for success.

In the *planet domain* functional biodiversity aims of the projects in the United Kingdom, Switzerland (vineyard project) and The Netherlands are clearly reflected. Success indicators of these projects are the enhancement of beneficial organisms and a reduction of pest populations. In the projects of Germany, Italy and the Swiss EFM project the nature conservation aims are dominant. Here the most important success indicators are related to the enhancement of specific species groups (plants etc.).

In the *profit domain* the functional biodiversity projects of the United Kingdom, Switzerland (vineyard project) and The Netherlands focus their success indicators on the reduction of pesticide use and reducing costs from pest control measures. However, also in the projects of Italy and Germany issues concerning the reduction of pesticide use and the costs related to pest management control strategies are being mentioned as important for success. In four of the projects the incorporation of the management measures into agri-environmental schemes and subsidies is mentioned. It is interesting that the cost-benefits in economic terms of the change in landscape management for other stakeholders in the countryside (related to for example rural development) is not mentioned as an important success indicator by any of the projects.

Spatial scale and generalisation

Analysis of the scale at which the PPP indicators were applied (Table 2) showed that the projects with a direct focus on functional biodiversity are centred around the field and farm level. Only in the Netherlands is the landscape/region level taken into account (including other actors than farmers). The projects that are primarily dealing with biological conservation do have a certain focus on the landscape/region level combined with a farm (Italy) or field level (Germany) approach. We also analyzed the extent to which projects paid attention to scaling out, i.e. addressing actors at the same scale outside the projects, and scaling up, i.e. extrapolation to scales higher than the one in the projects. It appeared that while scaling out was general, scaling up was only being addressed by projects in Switzerland and the United Kingdom.

Functional biodiversity and conservation biology: partners or opponents?

It should be mentioned that the analysis presented here could only be seen as a first step in evaluating success stories in landscape management for functional biodiversity. Therefore, the results presented first and foremost serve the purpose of initiating discussion.

The case studies which have been analyzed show that in all projects all three domains are being investigated. The people dimension is much more studied than initially expected. The projects primarily related to the functional biodiversity first of all have a focus on indicators relevant for farmers: acceptance by farmers, direct pest/natural enemies levels and pest management costs and savings at the field and farm scale. Projects with an emphasis on biological conservation in the countryside often also take into account functional biodiversity aspects, but mostly related to a wider setting: the landscape level and different stakeholders involved. Since the enhancement of landscape management for biological conservation reasons is rather successful, it can be questioned how the more classic functional biodiversity approaches can learn from this success. If we can bring functional biodiversity under the umbrella of a wider biological conservation aim or even in line with sustainable development of the countryside, for example by including more stakeholder groups and not limit our efforts to the farm level only, we might be more successful. In that case we should be aware that although it is mentioned that in most cases there is a win-win situation between both approaches, there may also be some trade offs. For example, should new established field margins be sown with crop species or endemic plant species? This type of questions should be addressed in both the IOBC framework and with representatives from other stakeholders.

Table 1. Self-evaluation of projects in which Functional Biodiversity played a role in the objectives - identifying the most important success indicators per domain of sustainable development. For details on projects see text (UK = United Kingdom, CH = Switzerland: vineyard & EFM-project, NL = Netherlands, I = northern Italy, D = Germany).

	Indicator	UK	CH	NL	I	D
People	Acceptance of functional biodiversity by farmers	+	+	+		
	Acceptance of functional biodiversity by agricultural advisors	+				
	Number of farmers involved			+	+	+
	Network of stakeholders		+			+
	Acceptance by public		+			
	Influence on policymakers	+				
Planet	Reduction of pest populations	+	+	+		
	Increase of beneficial arthropods (abundance or diversity)	+	+	+		
	Reduction of water / soil contamination			+	+	
	Increase of plant diversity		+		+	+
	Increase of insect diversity		+			+
	Increase of bird diversity				+	
Profit	Reduction of pesticide use	+	+	+	+	
	Cost/benefit analyses of different pest control strategies	+		+	+	+
	Cost/benefit of landscape management			+		
	Cost/benefit of ecological compensation areas		+			
	Obligations in plant plots from pesticide compensation					+
	Subsidies		+			+
	Integration into biodiversity schemes	+			+	
	Promotion of small companies	+				

Table 2. Hierarchical level at which success indicators were applied in the projects described in the text, distinguished for the domains: o = People indicators; × = Planet indicators; + = Profit indicators.

	United Kingdom	Switzerland	Netherlands	Italy	Germany
Field/crop	×	o ×	× +	x	× +
Farm	o × +	o × +	o × +	o ×	o
Landscape/region			o × +	o × +	o +

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Spatial interactions between a parasitoid and flowering plant strips in an agroecosystem

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Abstract: The movement of insects between cropped and non-cropped habitats in European agroecosystems has been the research subject carried out by the Applied Entomology group of ETH Zurich for over a decade. This paper summarizes some results from our most recent studies. Firstly, a parasitoid native to Europe can be tracked in the field based on the sedentary host caterpillars marked by the released parasitoid wasps through oviposition. Secondly, the released wasps parasitized host caterpillars in a random manner over the entire habitat patch of 1225 m^2 within a three-day exposure period in the presence of flowering dill plants. Thirdly, feeding on these floral nectar plants significantly increased flight performance of the parasitoid in a laboratory experiment. These findings are discussed with regard to spatial interactions between a parasitoid and flowering plant strips in an agroecosystem.

Key words: parasitoid, nectar plant, dispersal, flight

Introduction

The optimal function of a cropping system relies on the best possible utilisation of natural resources, including the spatial design of cropped and non-cropped areas. Non-cropped areas adjacent to crop fields may provide insects with shelter as shown in the apple blossom weevil *Anthonomus pomorum* L. (Toepfer et al., 1999; 2000), or with food, as will be discussed in this contribution focussing on the hymenopteran parasitoid *Cotesia glomerata* (L.). This species is native to Europe, where it is frequently found to parasitize *Pieris brassicae* L. caterpillars on cabbage (Gu & Dorn, 2000). It is a gregarious endoparasitoid, undergoing various degrees of superparasitism (Gu et al., 2003). This tritrophic system is also a well-established model to address questions on nutritional ecology (e.g. Wäckers, 2001; Hausmann et al., 2005).

Little is known on the influence of nectar plants on the flight performance of a parasitoid because its spatial habitat use is difficult to trace, especially in the presence of a native population. Through an interdisciplinary approach, we addressed questions on spatial interactions between the parasitoid and flowering plant strips in an agroecosystem.

Two technologies have been further developed at ETH Zurich for tracking parasitism in the field in the presence of flowering plants, and for quantifying the flight capacity of parasitoids feeding on these nectar sources. The first technique relies on marking the parasitoid with a rare stable isotope, and the second technique on measuring flight parameters in the nectar-fed parasitoids on a computerized flight mill adjusted to the parasitoid measuring only 3 mm in body length.

Material and methods

Field experiments relying on parasitoid marking with a stable isotope

To track the parasitism of *C. glomerata* on *Pieris brassicae* in the field, the rare stable calcium isotope ^{44}Ca was used as an internal marker. In two subsequent trials, ^{44}Ca-enriched parasitoids were released in the centre of two trial plots in an organically managed cabbage field in a region known to harbour natural populations of *C. glomerata* (Province Zurich, Northern Switzerland; 2004). Flowering dill plants (*Anethum graveolens* L.) were arranged at two diagonally opposite corners of each field plot, and non-flowering dill plants at the two remaining corners (Fig. 1). Parasitism by released wasps was determined through calcium isotope analysis of the recovered caterpillars using inductively coupled plasma mass spectrometry (ICPMS) (Hattendorf et al., in press).

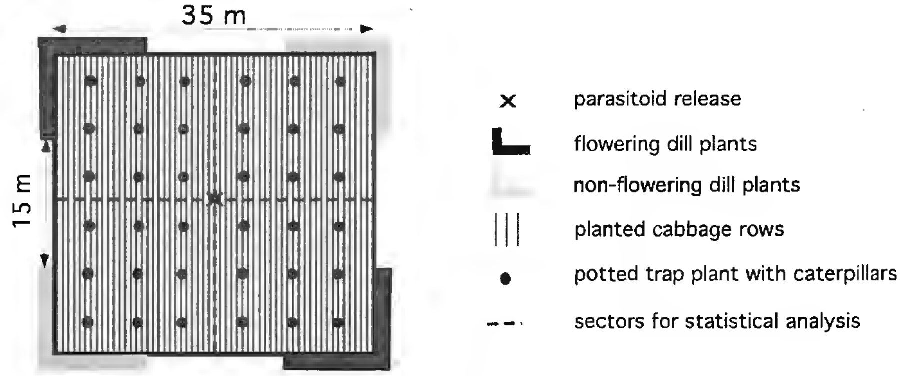

Figure 1. Field trial design showing one plot with *C. glomerata* parasitoids released in the centre, and parasitism assessed with host-infested trap plants in four sectors, adjacent to flowering or non-flowering dill plants.

Laboratory flight experiment

A computer-linked flight monitoring device, the flight mill, was adjusted to quantify the individual flight performance of the wasps (n = approx. 20 per treatment). To secure the wasps to the flight device, a pin was glued on the thorax of each wasp. The pin was pushed vertically through a flight arm, which started to rotate with flight initiation of the wasp. Each revolution was registered and recorded by a computer (Hughes & Dorn, 2002). The wasps were tested for 16 hours. Prior to the flight experiment, the newly emerged wasps were allowed to feed *ad libitum* on one of the food sources (Fig. 2) for either one or three days. As the flight data did not differ significantly for the two wasp groups, data were pooled for final analysis (Wanner et al., 2006).

Results

Field experiment

On average as many as 65% of the trap plants bore caterpillars parasitized by the released wasps in the two trials with the two 1225m^2 plots each (Fig. 1). A random spatial distribution of parasitism was documented by the fact that plants with ^{44}Ca marked caterpillars displayed no spatial autocorrelation. Intriguingly, the number of trap plants bearing parasitized caterpillars did not differ among the four sectors of the plots, i.e., parasitism rate in sectors adjacent to the non-flowering dill plants was similar to that in sectors adjacent to flowering dill plants (H. Wanner, H. Gu, D. Günther, S. Hein and S. Dorn, unpublished manuscript).

Laboratory flight experiment

Flight performance in female wasps feeding *ad libitum* on the floral nectar of dill was as high as in those fed on honey, and significantly superior to flight performance in wasps fed with water only (control) and those fed on sucrose (Fig. 2). In male wasps, no significant increase in flight performance was shown after feeding on dill or any other food source tested.

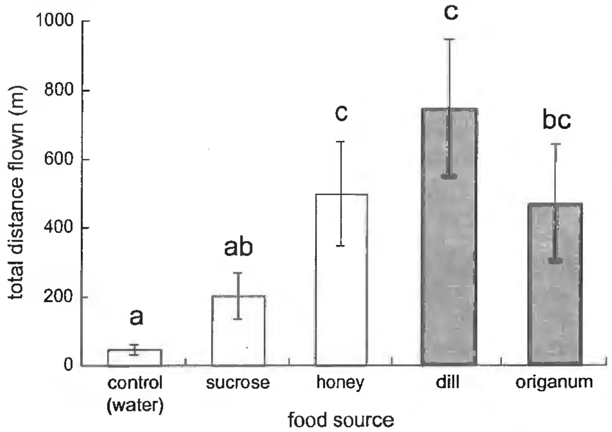

Figure 2. Laboratory experiment with *C. glomerata* female wasps after feeding on different food sources. Flight performance is presented as the total distance flown on a computer-linked flight mill.

Discussion

Marking *C. glomerata* with the stable isotope ^{44}Ca has proven to be a powerful tool for tracing spatial distribution of parasitism in field trials with flowering plant strips, even in the presence of a natural parasitoid population. Displacement of the released parasitoids was assessed based on the relatively sedentary host caterpillars marked through parasitism. This unique feature allows studying the spatial habitat use of released parasitoids without the necessity of recapture, which is often a critical aspect in the use of classical external or internal marking with dye (Toepfer et al., 2000; Keil et al., 2001). In classical mark-release-recapture studies, human interference with the released insects is indispensable and recapture rates are sometimes low. Furthermore, this new technique does not require elimination of the natural population prior to the release of the marked wasps by insecticide sprays, which may influence parasitoid behaviour on their turn.

Results from the field experiment in the presence of flowering dill plants indicate considerable habitat exploitation by the parasitoid in space and time. A random parasitism pattern was shown on the plots extending over 1225 m^2 each without any edge effect within a three days period. We suppose that this excellent utilization of the habitat patch has been achieved by female wasps commuting between the flowering nectar plants and the host bearing plants, but further studies are required to substantiate this postulate (H. Wanner, H. Gu, D. Günther, S. Hein, S. Dorn, unpublished manuscript).

Factorial experiments carried out in the laboratory support the expected increased flight performance of *C. glomerata* wasps after feeding on floral nectar plants. Dill and origanum (*Origanum vulgare* L.) proved to provide nutrients that were readily converted to flight energy. A comparison between dill with floral nectar and *Vicia faba* L. with extrafloral nectar clearly indicated the advantage of dill as an energy source to enhance flight performance in *C. glomerata* (Wanner et al., 2006). Thus, the availability and the quality of nectar sources may determine, to a large degree, the flight capacity of parasitoids and the range they will search for hosts. In conclusion, the presented field experiment in conjunction with the laboratory analysis shed a new light on spatial interactions between flowering plants and this parasitoid in an important agroecosystem.

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Soil structure and abundance of the entomopathogenic soil fungus *Metarhizium anisopliae* in wildflower strips

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Abstract: Several plant and animal species are promoted by wildflower strips. So far, potential benefits of this ecological compensation element to the soil have not yet been examined. Therefore, in the Swiss midlands (cantons Aargau and Basel-Land) the quality of the soil structure and the abundance of the entomopathogenic soil fungus *Metarhizium anisopliae* have been studied in five or six years old wildflower strips and were compared to cereal fields and permanent meadows.

Compared to the cereal fields the quality of the soil structure was better in the permanent meadows in both the topsoil (0-12 cm) and the under layer (25-35 cm). The values of the wildflower strips were in between. *M. anisopliae* was detected in all areas. The highest frequencies and densities were found in the permanent meadows. In the wildflower strips the fungus density tended to be higher than in the cereal fields. Thus, arable soils can benefit from establishing wildflower strips.

Key words: wildflower strip, cereal, permanent meadow, soil structure, entomopathogenic soil fungus, evaluation

Introduction

To counteract the loss of biodiversity in agricultural landscapes, the implementation of compensation measures has since 1992 become an important objective in Swiss agricultural policy. Wildflower strips sown with indigenous wildflower species are the main type of ecological compensation area on arable land. These strips have a minimum width of 3 m and may be maintained in the same place for two to six years. Though artificial, wildflower strips fulfil many goals of agroecology and nature conservation. They have been shown to increase the diversity of flora and fauna (e.g. Weibel, 1999; Pfiffner & Luka, 2000; Ullrich, 2001; Schwab, 2002) and can augment natural enemies and thus diminish agricultural pests (e.g. Pfiffner et al., 2003; Pfiffner & Wyss, 2004).

Potential benefits of wildflower strips to soil aspects, however, have not yet been studied. As the strips are neither fertilised nor treated with pesticides and remain untilled for many years, positive effects are imaginable. We therefore examined the quality of the soil structure and the abundance of the entomopathogenic soil fungus *Metarhizium anisopliae* which is widely-used for biological pest control. Old wildflower strips were compared to cereal fields and permanent meadows.

Material and methods

In the Swiss midlands (cantons Aargau and Basel-Land) 20 regions containing one five or six years old wildflower strip, one cereal field and one at least ten years old permanent meadow were chosen (Table 1). In each region the distance between the three areas ranged from a few meters to half a kilometre. Within each region the three areas had the same soil type. Soil samples were taken between end of April 2005 and beginning of June 2005.

Table 1. Number of plant species and proportion of plant cover and grasses in the wildflower strips and permanent meadows. The vegetation surveys were done in July 2005 in the location where the soil samples had been taken (approx. 35 m^2 per area).

	wildflower strips			permanent meadows		
	minimum	maximum	mean	minimum	maximum	mean
number of plant species	11	40	25.9	9	36	19.3
area of soil covered with plants (%)	80	100	96.7	85	100	93.4
area of soil covered with grasses (%)	1	80	21.8	20	100	52.4

Soil structure

In each area three soil samples of the topsoil (0-12 cm) and the under layer (25-35 cm) were taken. To evaluate the quality of the soil structure a method of visual classification was used (Nievergelt et al., 2002). A standardised, semi-quantitative description and evaluation of the soil structure in the two layers was achieved by assessing the size distribution of aggregates by fractionising, determining all types of aggregate present in each fraction, and judging the mechanical properties of the soil structure by the inter- and intra-aggregate strength (Nievergelt et al., 2002). From these parameters a quality value was calculated. The higher the value, the better the soil quality. Generally, agricultural soils show values between four and twelve. If the value of the topsoil is above nine and that of the under layer above seven, growth of the crops is not limited by the soil.

Soil fungus M. anisopliae

In each area ten soil samples consisting of two soil cores were taken. For the analysis the depth from 5 to 15 cm with a diameter of 5.5 cm was used. The isolation of the fungus followed Fornallaz (1992). 20 g/sample of fresh soil were shaken for 3 h in 200 ml Erlenmeyer flasks with 100 ml tap water containing 1.8 g/l tetra-Sodiumpyrophosphate. After 15 s of sedimentation 0.1 ml of the suspension was distributed with a spatula on a Petri dish with selective media (Strasser et al., 1996). Three replicates per soil sample were prepared. After 10 days of incubation at 22°C the colonies of *M. anisopliae* were counted.

Statistical analysis

Soil structure data were analysed with one-way ANOVA. Per area the mean of the three soil samples was used. Not normal distributed data were transformed logarithmically. Soil fungus data were analysed using a Kruskal-Wallis test. Of the ten samples per area the median was calculated. All data were analysed using STATISTICA 6.

Results and discussion

Overall, the quality of the soil structure was good. The values in the topsoil were higher than in the under layer (Fig. 1). This probably was because of a higher amount of humus and a higher biological activity in the topsoil. The values in the topsoil and in the under layer were highest in the permanent meadows and least in the cereal fields (Fig. 1). The quality of the soil structure in the wildflower strips was in between.

M. anisopliae was not detected in all soil samples, but in all areas. The highest frequencies and densities were found in the permanent meadows (Table 2, Fig. 2).

Compared to the cereal fields, in some wildflower strips the fungus also was more abundant (Fig. 2). Similar observations were made in other parts of Switzerland where densities of *M. anisopliae* were higher in meadows than in arable crops (Keller et al., 2003; Rodrigues et al., 2005). Low densities of the fungus in arable soils seem to be related to the scarcity of hosts due to soil cultivation and the input of fertilisers and pesticides (Keller et al., 2003).

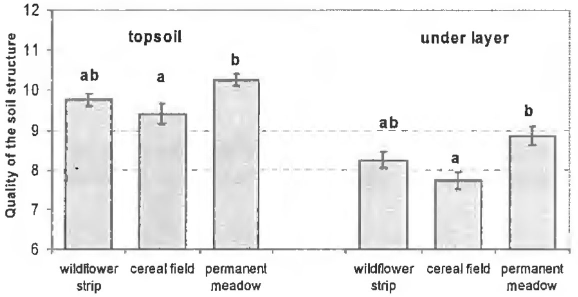

Figure 1. Quality of the soil structure in the topsoil (0-12 cm) and in the under layer (25-35 cm); n = 20; means and standard errors. $p_{topsoil} = 0.011$; $p_{under\ layer} = 0.002$. Significant differences are indicated by different letters (Tukey post-hoc test, $p < 0.05$).

Table 2. Frequency (% positive soil samples, % pss) and density (colony forming units per gram soil, CFU/g) of *M. anisopliae*. n = 20, 10 soil samples per area. Median: $p_{crop} < 0.001$; mean: $p_{crop} < 0.001$. Significant differences are indicated by different letters (Tukey post-hoc test, $p < 0.05$).

		M. anisopliae (CFU/g)			
crop	% pss	median	mean	standard deviation	standard error
wildflower strip	64 ± 5	42^b	126^b	228	15
cereal field	54 ± 7	20^b	25^b	20	5
permanent meadow	86 ± 4	144^a	316^a	348	19

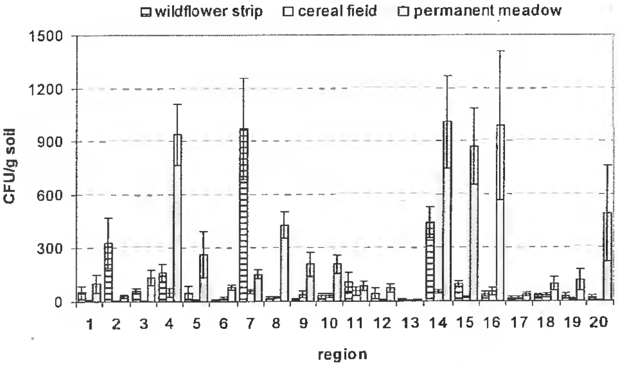

Figure 2. Density of *M. anisopliae* in colony forming units (CFU) per gram soil in the 20 regions. Means and standard errors of 10 soil samples.

It is concluded that wildflower strips can improve the structure of arable soils. Moreover, the density of *M. anisopliae* tends to be increased by wildflower strips.

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Contribution of sown wildflower areas to cereal aphid control: from local to landscape scale

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Abstract: Sown wildflower areas and other non-crop habitats often support high densities of arthropod predators and parasitoids. Biological control in nearby crop fields should thus be enhanced. However, evidence for such positive influences is limited, and complicated by the fact that the spatial scales across which beneficial arthropods act are uncertain. We excluded flying predators and parasitoids from forty plots of winter wheat to quantify their influence on aphid populations. We expected higher aphid control (i) at the edge compared to the centre of fields, (ii) in fields with adjoining sown wildflower areas compared to grassy field margins, and (iii) in landscapes with relatively high percentages of open perennial habitats. Aphid densities decreased towards the edge in fields with adjoining sown wildflower areas, but were higher at field edges next to grassy margins. The difference in aphid densities between the open treatments and plots where flying enemies were excluded increased with the percentages of open perennial habitats in the surrounding landscape. Thus, beneficial effects of non-crop habitats could be seen both in local edge effects and in the composition of the wider landscape. This encourages further research on the spatial design of agroecosystems for improved biological control.

Key-words: biological control, cereal aphids, landscape structure, sown wildflower area, winter wheat

Introduction

Habitat degradation and increasing intensity of agricultural practises are main causes of biodiversity loss in Europe. A possible negative side-effect of decreasing biodiversity is the loss of natural pest control. Agri-environment schemes aim to halt biodiversity loss and thereby conserve the important ecosystem service of natural pest control. Sown wildflower areas are a part of the Swiss agri-environmental programme designed specifically for arable landscapes. They are sown with annual and perennial herbs and wildflowers and left undisturbed for six years, after which they are replaced with arable crops. While their benefit to biodiversity has been well documented (Frank & Nentwig, 1995; Jeanneret et al., 2003), there is very little evidence to date regarding their influence on ecosystem services, so far. Cereal aphids can be serious pests in Central European winter wheat. They are preyed upon by a wide range of insects, spiders and entomopathogenic funghi (Plantegenest et al., 2001; Schmidt et al., 2003, 2004a). As both aphids and many of their natural enemies are very mobile, not only the crop field itself and its immediate surrounding, but also the wider landscape context may be important for local biological control (Schmidt et al., 2004b). Patterns of aphid densities and parasitism suggest that biocontrol is higher in landscapes with high percentages of non-crop habitats (Thies et al., 2005). However, experimental evidence of enhanced biocontrol in complex landscapes is - to the best of our knowledge - still missing.

We conducted experiments in winter wheat to test how aphid suppression depends on the landscape context. We expected higher aphid control (i) at the edge compared to the centre of fields, (ii) in fields with adjoining sown wildflower areas compared to grassy field margins, and (iii) in landscapes with high percentages of open perennial habitats compared to landscapes dominated by annual arable crops.

Materials and methods

The study was carried out in twenty fields of winter wheat in the Swiss Plateau. The fields were distributed across ten landscapes which formed a gradient from 11% to 34% of perennial open habitats within 1.5 km radius. In each landscape, a pair of fields with and without adjoining sown wildflower area was chosen 300 m – 500 m apart from each other. The sown wildflower areas had an average size of 1.14 ± 0.19 ha (min: 0.74 ha, max: 2.37 ha). In each field, two study plots were installed 3 m ('edge') and 30 m ('centre') from the field edge, respectively. All fields were managed with reduced chemical inputs and received herbicides, fungicides and predominantly mineral fertilizers, but no insecticide sprays. Land-use was hand-mapped based on VECTOR25 data supplied by the Bundesamt für Landestopographie (Wabern, Switzerland) and analysed in a Geographic Information System (ArcGIS 9.1; ESRI Inc, Redland, California).

In each of the 40 study plots, one wire cage covered with sprayable insect glue was installed to deter or intercept flying aphid enemies. The cages were 1.2 m high, covered a circular area of 0.8 m^2 and had quadratic mesh with 6 mm openings. The cages were installed during wheat flowering, when aphids had colonized the wheat, but when natural enemy densities were still low. Two weeks later, at the milk ripening stage, aphids and their natural enemies were counted on 30 stems of wheat within and outside of each cage. The difference between the cage and the open field was expected to reflect the intensitiy of aphid suppression by their flying natural enemies. Log-transformed aphid densities were analysed in linear mixed-effects models with nested random effects using the the 'nlme' library in R (Pinheiro et al., 2005; R Development Core Team 2005). Data from three landscapes could not be analysed because a thunderstorm and a plant disease had affected the experimental plots.

Results and discussion

Metopolophium dirhodum was the most abundant aphid species. Its densities tended to decrease with increasing percentages of open perennial habitats in the surrounding landscape (Table 1). The change of aphid densities towards the field edge was dependent on the type of adjoining habitat (Figure 1A), as expressed by the significant interaction between the factors wildflower area and position (Table 1). In fields with adjoining sown wildflower areas, aphid densities decreased towards the field edge. In contrast, fields with adjoining grassy margins had higher aphid densities at the edge compared to the centre. As this pattern was independent of the exclusion cages, it could reflect differences in aphid colonization or the action of ground-dwelling natural enemies which are not affected by the wire cages (Schmidt et al., 2003, 2004a).

In agreement with our third hypothesis, there was a significant interaction between the influence of landscape composition and cage treatment (Table 1). Inside the cages, aphid densities were relatively unaffected by landscape composition (Figure 1B). In the open field however, aphid densities decreased with increasing percentages of open perennial habitats. The difference between the regression lines can be ascribed to aphid predation by natural enemies. Hence, flying enemies in the open fields appeared to suppress aphid densities more effectively in structurally rich landscapes.

Table 1. Effects of landscape composition, adjoining wildflower area, position within the field and cage on densities of the aphid *Metopolophium dirhodum* at milk ripening of wheat.

	d.f.	t	p
landscape	11	-2.1	0.060
wildflower area	6	0.8	0.438
position	11	1.1	0.280
cage	26	0.6	0.586
wildflower area × position	11	-2.2	0.047
landscape × cage	26	2.3	0.033

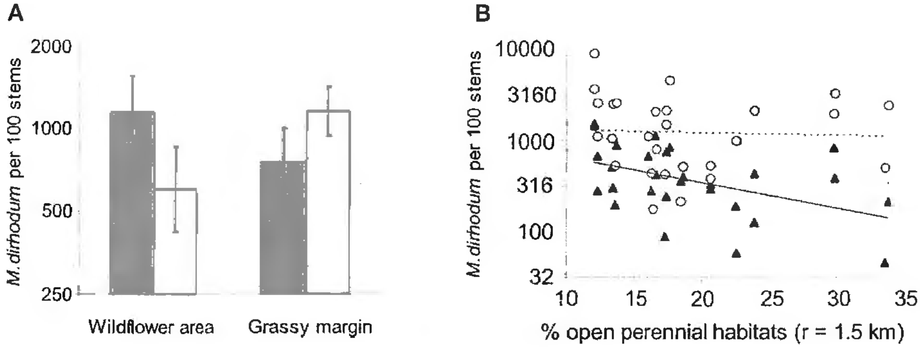

Figure 1. (A) Abundance (± SE) of *M. dirhodum* in the centre (grey bars) and at the edge (white bars) of wheat fields in relation to the adjoining habitat type. (B) Abundance (log transformed) of *M. dirhodum* in the cages (open circles) and on the open field (solid triangles) in relation to the percentage of open perennial habitats. For statistics, see Table 1.

In previous studies, declining pest densities with increasing landscape heterogenity have been related to higher levels of parasitism (Thies et al., 1999; Thies et al., 2005). In the present study however, parasitism of *Metopolophium dirhodum* (recorded as the percentage of mummies) was only 0.9 %. This suggests that other groups of enemies were important. Insects glued to the exclusion cages included Syrphidae, Dolichopodidae and Staphylinidae. The roles of these predator groups require further investigation.

In conclusion, aphid densities were reduced in the immediate vicinity of sown wildflower areas, and in landscapes with high percentages of open perennial habitats. This is encouraging for the further investigation of functional biodiversity on a landscape scale, especially in combination with field experiments and under consideration of the entire range of potential biocontrol agents.

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Exploring the potential of green veining to support pest management: a multi-scale optimization approach

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Abstract: Green veining in agricultural landscapes can provide a habitat for natural enemies of crop pests, which could reduce the need for chemical crop protection. Design and assessment of agricultural landscapes can be supported by exploration of the potential to effectively combine economic performance, environmental sustainability and the use of green veining. The Landscape IMAGES methodology enables spatially explicit exploration of options by multi-objective optimization, for multifunctional agriculture in landscapes at a scale of a few km². The functioning of the method is illustrated with a hypothetical example of an arable-cropping dominated farm with field margins bordering the fields. The trade-off between gross margin from cropping and chemical pesticide use is explored. The potential contribution of natural enemies from field margins to pest suppression in crops is evaluated. This approach could contribute to the landscape scale exploration of possibilities to enhance the beneficial role of functional biodiversity in cropping systems.

Key words: functional biodiversity, pesticide use, trade-off analysis, differential evolution

Introduction

Increasing structural complexity in agricultural landscapes, for instance by reintroducing a mosaic structure of non-crop landscape elements (green veining), can contribute to increased parasitism and reduced crop damage by pests (Thies and Tscharntke, 1999). Additional non-crop plant resources in agricultural landscapes dominated by the simple habitats of annual crops can lead to the creation of suitable habitats for reproduction, feeding and sheltering for a number of beneficial arthropod species (Landis et al., 2005). The potential of field margins as reservoirs of the natural enemies of crop pests is widely accepted (Altieri, 1999). However, from an agronomic perspective the effectiveness of these landscape elements in providing crop protection depends on many factors, for instance the dispersal ranges of natural enemies into the crop area, the responsiveness of the crop pest to predation (predator-prey dynamics) and the eventual effects on crop herbivory. Moreover, the financial costs and benefits of introducing non-crop landscape elements relative to artificial crop protection measures will be crucial decision making criteria for the land manager. Taking these considerations into account, designing a mosaic landscape would involve optimizing the allocation of field margins within arable cropping landscapes, thereby enhancing the dispersal of natural enemies and thus stabilizing pest populations (Boatman, 1994; Fry, 1995). In this paper we present a prototype version of a Landscape IMAGES methodology that enables spatially explicit landscape design. It provides the possibility to explore the trade-offs between gross margin and pesticide use, and the role of field margins at landscape scale. The Landscape IMAGES methodology is illustrated with a hypothetical example of functional biodiversity design at the farm scale.

Methods

Conceptual model

The assessment of the performance of a given farm or landscape can be based on multiple criteria, such as gross margin, pesticide use and presence of field margins. Various land-use activities make different contributions to the performance criteria and the activities of spatial units may interact with respect to the performance criteria. Consequently, different configurations of activities result in different values of the performance criteria. The exploration of the trade-offs between performance criteria or objectives can be formulated as a multi-objective design problem, which can be generally stated as follows.

$$\text{Max } \mathbf{U}(\mathbf{x}) = (U_1(\mathbf{x}), U_2(\mathbf{x}), \ldots , U_k(\mathbf{x}))^T \qquad (1)$$

$$\mathbf{x} = (x_1, x_2, \ldots ,x_n)^T \qquad (2)$$

Subject to i constraints:

$$g_i (\mathbf{x}) \leq h_i \qquad (3)$$

Where, $U_1(\mathbf{x}),\ldots,U_k(\mathbf{x})$ are the objective functions that are simultaneously maximized or minimized, and $(x_1,\ldots,x_n)$ are the decision variables that represent the activities allocated to the n spatial units. The decision variables can take on a predescribed array of values, $\mathbf{x} \in S$, where S is the solution or parameter space. Constraints (Eq. 3) can arise from the problem formulation, for instance by limitations on the inputs or outputs related to the activities. Heuristic techniques such as genetic and evolutionary strategies can be employed to obtain approximations of the trade-off surfaces by a population of solutions, each representing a configuration of activities for the landscape. In this study, the trade-offs between the objectives were explored with a multi-objective implementation of the evolutionary algorithm of Differential Evolution (DE) developed by Storn and Price (1995). Details on the conceptual model and the optimization approach are provided in Groot et al. (2006).

Allocation of crops and natural or chemical crop protection

In the model agricultural land-use on the fields and the placement of field margins adjacent to the fields are allocated in an optimal manner, taking into account spatial heterogeneity and spatial interactions. In the current prototype implementation the model seeks to maximize gross margin and to minimize pesticide use for a hypothetical farm of 65 ha with two crops which were randomly allocated to the fields (Figure 1).

Using the Differential Evolution algorithm, a collection of landscape configurations differing in the pesticide use on fields and in the presence of field margins at field boundaries was generated, which represents the trade-off between gross margin and pesticide use. Additionally, to determine the field margin effect, the trade-off was also established for a

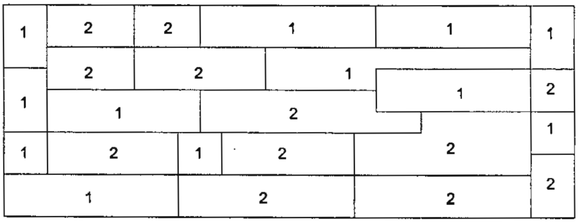

Figure 1. Hypothetical farm area (500 x 1300 m²), consisting of 24 fields with fixed allocation of crop 1 or 2 and field borders which may be managed as margins with functional biodiversity (FB). Total area of crops 1 and 2 amounted to 30.25 and 34.75 ha.

situation without any field margins. The crop allocation to the fields remained fixed throughout the optimization.Field margins were assumed to have a fixed width of 3.5 m, occupying 1.75 m within each adjacent field, where no crop was grown. Field margins were considered as sources of natural enemies for crop pests. The natural enemies were assumed to penetrate actively into the crop, with a dispersal range into the field of 30 m. Within this range no pesticide was applied.

The returns from cropping were assumed to increase due to chemical crop protection and natural pest suppression, but to different extents for the two crops (Table 1). For field margins, a subsidy of €1250 per ha and costs of €40 per ha were assumed. The trade-off between pesticide use and gross margin was determined for situations with and without use of field margins.

Table 1. Characteristics of hypothetical crops 1 and 2: gross margin (€ per ha) without pest protection and with protection by natural enemies from field margins and by pesticides. The required application rate in case of pesticide use is given.

Crop	Gross margin (€ per ha)			Pesticide application rate (kg per ha)
	Unprotected	Natural	Pesticide	
1	800	1295	1350	5
2	950	1140	1305	12

Results

The trade-off between gross margin and average pesticide application rate is presented in Figure 2a, for landscapes without and with (varying) number of field margins. Uptake of field margins contributed considerably to gross margin, in particular when average pesticide application rates were limited to a maximum of 2 kg per ha. In the range of 2 to 8 kg of pesticide per ha the economic return on pesticide use was less in the field margin landscapes compared to the margin-less landscapes, due to the beneficial effect of the use of field margins on gross margin (Figure 2a).

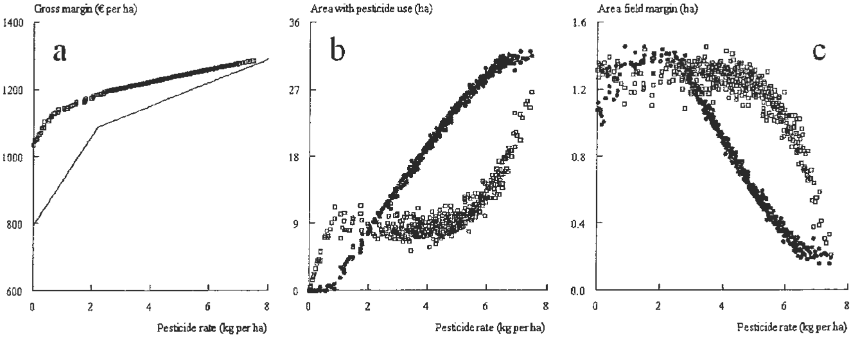

Figure 2. a. Trade-off between gross margin and pesticide application rate without (line) and with (symbols) field margins in a hypothetical illustration. The relation between average pesticide application rate and the area receiving pesticide application (b) and the area occupied by field margins (c) for crop 1 (□) and crop 2 (●).

In margin-less landscapes reducing pesticide use first reduced for crop 2 with the high pesticide application rate (data not presented). In contrast, in field margin landscapes restricting pesticide use caused uptake of field margins and less pesticide use particularly with crop 1 (Figures 2b and 2c) which was characterized by effective pest suppression by field margins (Table 1). The variation in areas of pesticide and field margin use per crop at each level of pesticide use indicated that points in the trade-off curve could be realized by different landscape configurations. This reveals the options for choice by stakeholders.

Discussion

The application of the Landscape IMAGES framework to the hypothetical example demonstrated that trade-offs between multiple objectives can be effectively explored in a spatially explicit land-use allocation problem. The solution sets contained a large range of possible configurations of the landscape in terms of land-use on fields and the placement of margins on field boundaries. Moreover, the presented approach provided a clear insight into the trade-off between gross margin from cropping and the use of chemical pesticides, and into the potential contribution of field margins for different objectives at the landscape scale (Figure 2a).

To go from the hypothetical example to calculation of trade-offs between objectives in real-world situations requires more detail in ecological, agronomic and economic relations. Many of these are available and the Landscape IMAGES approach provides a framework for integration of information. When integrated with population dynamic modelling as for instance demonstrated by Bianchi and Van Der Werf (2003), the framework offers opportunities for landscape scale evaluation of movements and dynamics of populations in heterogeneous environments from economic, ecological and environmental perspectives. Such multi-objective evaluation is considered crucial to improve understanding of population and community ecology (Cronin and Reeve, 2005) and functional biodiversity (Altieri, 1999).

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Enhancement of the Dock Leaf Beetle (*Gastrophysa viridula* Deg.; chrysomelids) by extensive grassland management

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Abstract: The chrysomelid beetle *Gastrophysa viridula* is an oligophagous feeder of the broad-leaved dock (*Rumex obtusifolius*, Polygonaceae), a harmful weed in grassland in many regions of Austria. The larvae of *G. viridula* feed on dock leaves and therefore are considered a promising biocontrol agent against *R. obtusifolius*. The objective of this study was to clarify whether the dock leaf beetle can be enhanced by appropriate grassland management. In a plot experiment (plot size: 9 x 25m, two replications) set up in Hohenlehen/Lower Austria in spring 2000, the following treatments were investigated for *G. viridula* densities, larval feeding-damage on the docks, beetle migrations and dock coverage: (1) unmown, (2) beetle-friendly mown (2x mowing, after larval migration into the soil for pupation), and (3) normally mown (3x mowing, without considering larval migrations) as a control. In early summer 2000, in unmown and beetle-friendly mown plots higher beetle densities and larval feeding damage on dock leaves was found. In late summer 2000, beetles in high densities had spread across all experimental plots. Subsequently, dock leaves were damaged irrespective of the treatment. In late autumn, beetles moved from the adjacent plots into the unmown plots. In spring 2001 far more overwintered beetles emerged from the soil in the unmown plots than in the control plots. From there, they began to spread across the pasture. From 2000 to 2003, dock plant coverage considerably had declined in the unmown plots. DLB feeding damage might have contributed towards this decline.

Key words: *Gastrophysa viridula*, *Rumex obtusifolius*, dock leaf beetle, broad-leaved dock, biological weed control, mown pasture, grassland, organic farming

Introduction

The broad-leaved dock (*Rumex obtusifolius*, Polygonaceae) is a harmful weed in grassland, since it reduces both yield and quality of the fodder due to its high biomass and content of tannins and oxalic acid. The dock problem is particularly severe in organic grassland farming, because there are no effective means of regulation except for manual dock-pulling (Zaller 2004). The herbivorous dock leaf beetle (DLB) (*Gastrophysa viridula*; Chrysomelidae) is an autochthonous antagonist of broad-leaved docks. It is 4-6mm long and gold to bluish-green in colour. The females have extremely swollen abdomens during egg-laying period. Between end of March and end of April DLBs leave their overwintering sites and immediately start copulation. Then the females lay their bright-yellow eggs in batches of 30 to 40 on the underside of the dock leaves. After hatching the black-coloured DLB larvae pass through 3 larval stages. After 3 to 4 weeks the last instars dig 2 to 5cm into the soil directly beneath the host plant for pupation. In Austria, usually three generations are developed. The juvenile beetles of the last generation dig into the soil for overwintering in late autumn. The beetles migrate mainly by walking on the soil surface (Engel 1956, Benz 1982).

Since the DLB larvae can defoliate entire dock plants when they occur in high densities, the enhancement of this beetle offers a promising biocontrol method against *R. obtusifolius*. Therefore, in this study we investigated wether the dock leaf beetle can be enhanced by a mowing schedule adapted to larval developmental status and by unmown plots which might serve as hibernation sites. Furtheron, the performance of docks under the different treatments was monitored.

Material and methods

Site description

In spring 2000 a plot experiment (plot size 6 x 25m) with three different treatments and two replicates (Fig. 1) was established in a heavily dock-weeded, regularly mown pasture (600 m above sea level) at the Agricultural School Hohenlehen (Lower Austria). The following mowing schemes were investigated for their effects on DLB as well as dock performance: (1) unmown (um; no mowing), (2) beetle-friendly mown (bfm; 2 mowings: 14 June, scheduled after migration of the majority of DLB 1st generation larvae into the soil for pupation; 10 August), and (3) normally mown (nm; 3 mowings: 17 May, 21 June, 10 August; all scheduled as typical in the region) as a control.

Sampling and monitoring methods

For measuring DLB population densities during 2000, adults, egg-batches and larvae were counted on 20 to 50 randomly selected dock plants per plot. For estimating DLB feeding damage, grids were established over the plots (2 x 3m in July, 0.75 x 1m in August 2000) and the dock plant next to a grid-point was evaluated according to a newly-developed leaf-area-monitoring scale (Hann & Kromp 2001). Migration rates of DLB adults were monitored in autumn 2000 and spring 2001 by directional pitfall trapping (steel fences 2m x 0.6m, bent on top, pitfall traps on both sides close to both ends) alongside the borderline between um- and bfm-plots. DLB adult emerging densities in spring 2001 were measured with enclosures (steel frames 0.5 x 0.5m, covered with a 2mm net; 5 per plot) in um- and nm-plots. Ground cover of broad-leaved docks was estimated once in summer from 2000 to 2003, respectively, within a $1m^2$ frame, placed at 25 randomly scattered positions per plot.

Results and discussion

Dock leaf beetle feeding damage

Data on DLB population densities have been reported already elsewhere (Hann & Kromp 2001), showing a trend towards enhancement by unmown as well as beetle-friendly mowing. In July 2000, after the 1st cutting in the beetle-friendly mown plots and the 2nd cutting in the normally mown plots, the highest percentages of feeding damage on dock plants were monitored in the unmown plots followed by the beetle-friendly mown ones (Fig. 1). This is considered to be owing to better conditions for build up of 2nd generation DLB population under um- and bfm-mowing, whereas the 1st cutting in the nm plots very likely had disturbed 1st generation larvae before migrating into the soil for pupation. Accordingly, an enhancing effect of mowing schemes adapted to the population dynamics of the DLB has been reported by Benz (1982). In late August 2000, though, after 2nd cutting on the bfm-plots and 3rd cutting on the nm-plots, 3rd generation DLB adults had spread abundantly all over the experimental plots with subsequent larval feeding damages unrespective of the treatment, as has been found in the second grid evaluation, reported in Hann & Kromp (2001).

Dock leaf beetle migrations and spring emergence

In autumn 2000, mainly from beginning of October onwards, a migration of DLB adults into the unmown plots was revealed by directional pitfall trapping (Fig. 2). In spring 2001, many more DLB adults emerged from overwintering in the soil within the enclosures in the um-plots, compared to the normally mown ones (Tab. 1). Accordingly, beetles moved out of the um-plots in two waves at beginning and end of April 2001 (Fig. 2).

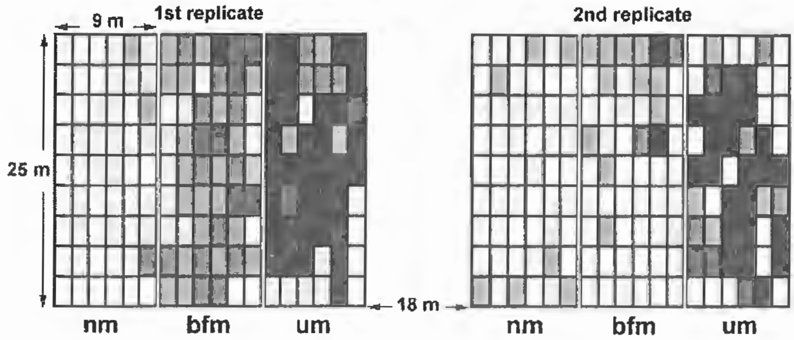

Figure 1. Estimation of DLB feeding damage on dock plants at 2 x 3m grid points on 21 July 2000. Intensity of grey shadings indicates percentage of DLB damaged leaf area: white = no dock plant at grid, light grey = 1%, ..., black = 65%, i.e. totally damaged.

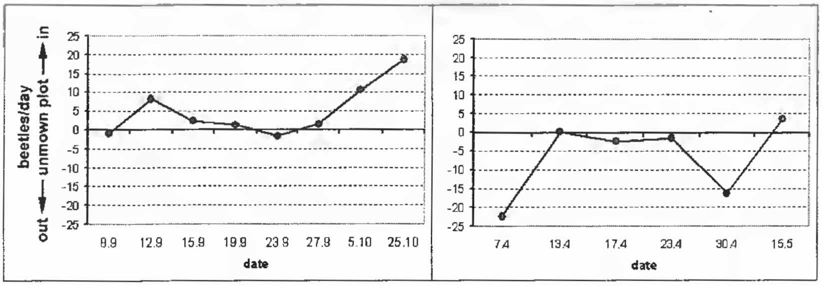

Figure 2. Migration rates of DLB adults, caught inside and outside directional pitfall-trapping fences alongside the border of the unmown plots in autumn 2000 (left) and spring 2001 (right).

Table 1. Total numbers of DLB beetles, emerged within enclosures (total enclosed area per plot: 1.25m²; 5 enclosures per plot) in normally mown and unmown plots in April 2001.

treatment	1st replicate	2nd replicate	sum
normally mown	8	14	22
unmown	140	140	280

Ground coverage of broad-leaved docks

From 2000 to 2003, ground coverage of dock plants had declined considerably on the unmown plots in both replications (Fig. 3). The leaf-feeding of DLB might have contributed towards this decline, although the performance of marked single plants with different degree of DLB feeding damage observed over the year has shown only a weak correlation between

DLB feeding damage and the disappearance of dock plants (Hann & Kromp 2003). Hatcher (1996) reported a severe effect of DLB herbivory between August and October on regrowth capacity and root quantity and quality of dock seedlings in the following spring. In our trial, besides DLB damage, the competition of grasses having built up a dense turf on the unmown plots very likely also had contributed to the reduction of broad-leaved docks.

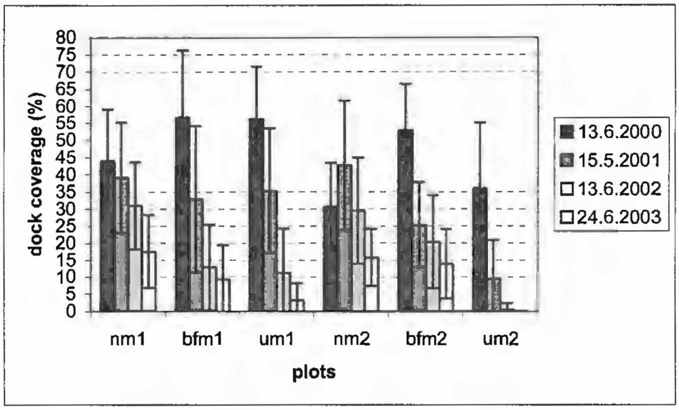

Figure 3. Mean percentage (+/- S.D.) of ground coverage of broad-leaved dock plants in plots under different mowing regimes (nm: normally mown, bfm: beetle-friendly mown, um: unmown) from 2000 to 2003.

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Regional adjustment of result-oriented agri-environmental schemes rewarding ecological goods on arable land is necessary

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Abstract: Result-oriented agri-environmental schemes rewarding ecological goods on arable land have a need for a regional adjustment. In a case study such a scheme was transferred from the regional district Northeim (German low mountain rage) to the regional district Bad Doberan (North-German depression). The results show, that an adjustment of the rewarding criteria becomes necessary, if the attributes of single associations notably differ from that of the criteria defining associations.

Key words: weeds, agri-environmental programs, goal-oriented, cross compliance, case study

Introduction

Weeds perform the only spontaneous contribution of arable fields to plant biodiversity. Thus, if agro-biodiversity is contemplated to be a significant output of multifunctional agricultural activities, the possibilities to reward their occurrence are of major interest. The appearance of the weed flora is strongly associated with husbandry measures. Hence, weeds can be utilized to ascertain the production of ecological goods and services on arable land within result-oriented agri-environmental payment schemes (Gerowitt et al., 2003). Such schemes cannot be transferred offhand from one region to another. Since the composition of the vegetation adapts to landscape structures, they require a regional adjustment of the rewarded ecological goods as well as of the rewarding criteria. This paper gives an example for this process.

Material and methods

The result-oriented payment scheme

Starting point for this study was a regionalized result-oriented payment scheme, developed by Bertke et al. (2005). The concept comprises of four components, of which the first is the result-orientation. This means, that the reward is based on the objective evidence of defined plant species diversity per control unit and not on the compliance with certain cultivation regulations. The result-orientation is combined with a regionalized implementation and adjustment of the concept. The concept is further based on a participative approach with a regional advisory committee (representatives of the regional administrative and political bodies and non-governmental organizations) deciding about the distribution of the available budget. These components are combined with a tendering procedure in which every participating farmer has to calculate an individual tender price instead of a fixed subsidy. For this study only the first two components are of relevance.

Within the described payment scheme specific rewarding criteria for ecological goods on arable land have been developed (Bertke, 2004). These are at first the total number of weed species per control unit after completion of all pest management measures (table 1), and second the existence of threatened weeds (red data list). By enhancing the required number of weeds per control unit four quality levels of ecological "goods" on arable land have been defined (12 to 24 weed species per control unit (100 m^2); figure 1).

Study region and data base

For testing the applicability of the result-oriented payment scheme on arable land the transfer region (regional district Bad Doberan) has been selected as to clearly differ from the original region, the regional district Northeim (German low mountain rage). The regional district Bad Doberan, Mecklenburg-Western Pomerania (1,362 km^2, 600 mm average rainfall p.a.) borders the Baltic sea near Rostock. It is part of the region North-German depression. The landscape is composed of different formations of the last ice age (outwash plain, ground and end moraines, glacial valleys). The base material for soil formation consists solely of the glacial sediments and mineral and organic formation (clay, sand, boggy soil). Since the 17th century the region around the town Bad Doberan is characterized by a large-scale agriculture (2003: 406 farms, average size: 240 ha).

For this study 381 relevés of arable land in the regional district Bad Doberan (dated 1980 till present) and a complete species list of its vascular plants (1,445 vascular plants) were made available. These data are part of the floristic data base of Mecklenburg-Western Pomerania. Also a compilation of the plant communities of the *Bundesland* and their areal distribution (Berg et al., 2004) was analysed for the studies purposes. The definition of the rewarding criteria for arable land was conducted by Bertke (2004) on the basis of field data of the INTEX project (Gerowitt, 2003). The results of her study were used as comparative data for this study.

Methods

The regional adjustment of a result-oriented payment scheme demands for a feasibility study of the rewarding criteria. For this purpose the relevant attributes of the regional weed communities were compared to each other. In case of the ecological goods on arable land the only relevant attribute is the medium number of species per surface unit of measure. The available relevés have been sorted and analysed (Microsoft® Office Excel 2003).

Results

Due to differences in landscape structures the weed communities of the study regions differ in some associations. In the regional district Bad Doberan, for instance, the typical associations of the hilly country and of loess soils do not occur. However the only association of importance is *Scleranthо annui-Arnoseridetum minimae*, occurring in Bad Doberan, but not in Northeim. Of all other communities the medium number of species per surface unit of measure does not vary fundamentally (Table 1). Therefore these weed communities possess equal chances to fulfil the rewarding criteria. *Scleranthо annui-Arnoseridetum minimae* is typically found on highly acid, sandy soils that are extremely poor on nutrients. Due to these extreme local conditions the community is relatively species-poor and disadvantaged in fulfilling the rewarding criteria. Hence an adjustment of these criteria is necessary. A new criteria was established, the soil pH-value: if the detected soil pH-value equals or is less than pH 4.5, the required number of weeds per control unit can be reduced by five for every quality level of ecological goods on arable land.

The following analyses were conducted to test the feasibility of the rewarding criteria in the transfer region. Figure 1 shows that typical weed communities of high intensive arable land in Bad Doberan seldom fulfil the rewarding criteria (*Aphano arvensis-Matricarietum chamomillae*, *Galeopsietum speciosae*), whereas weed communities of low-intensive cultivation do (*Scleranthо annui-Arnoseridetum minimae*, *Paveretum argemones*). Relevant numbers of threatened weeds can only be found in *Scleranthо annui-Arnoseridetum minimae* (56.5 % of these relevés) and *Paveretum argemones* (82.1 % of these relevés). The most frequent threatened weed is *Centaurea cyanus* (27.2 % of all relevés), followed by *Anthoxanthum aristatum* (13.1 % of all relevés). In total five threatened weeds were found in the relevés, all of these in relevés of *Scleranthо annui-Arnoseridetum minimae.*

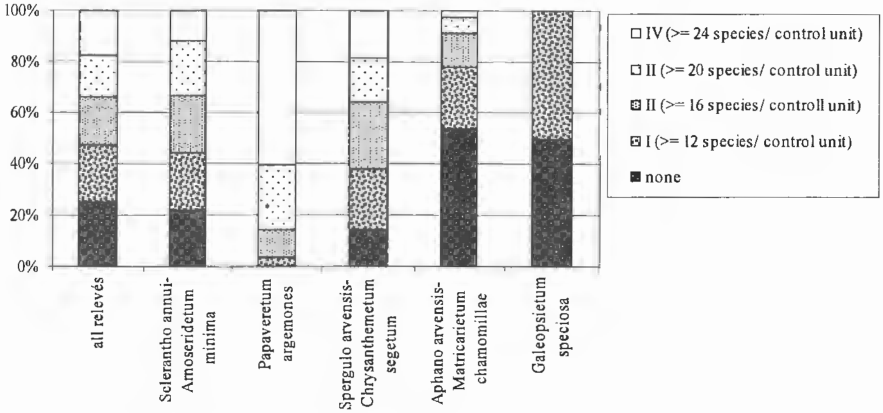

Figure 1. Level of quality of ecological goods on arable land (% relevés (N_{383})), Bad Doberan.

Discussion

The results show that the defined rewarding criteria are still feasible in the regional district Bad Doberan. An adjustment of these rewarding criteria can become necessary, if the attributes of single associations notably differ from that of the criteria defining associations.

50 % of the available relevés of arable land in the district Bad Doberan hold at least one threatened weed. A third of them account for *Centaurea cyanus*. The relatively frequent occurrence of these species in the district effects a clear upward shift of the determined quality level of ecological goods on arable land. Thus, it should always be kept in mind, that a single species can have a measurable influence on the decision, whether a field is worth rewarding or not.

From an agrarian perspective the occurrence of weeds on arable land is predominantly associated with negative side effects: competition for light and nutrients, hampering of the harvest, or reduction of crop quality. On the other hand weeds also possess quite a number of positive ecological, economical, cultural and aesthetical values (Höft & Gerowitt, 2006). The "production" of these benefits is an ecological service that in general can not be generated with regular husbandry measures. To be worth rewarding the expenditures to "produce" ecological goods and services have to exceed husbandry expenditures according to cross compliance regulations. The question is how result-oriented schemes can provide evidence of fulfilling this requirement. The occurrence of weeds is strongly influenced by the pesticide application. A pesticide application fulfils cross compliance regulations as long as the deployed dose does not exceed the specified maximum application rate as stated in the application instructions of the specific pesticide. This dose normally guarantees that the acre is free of weeds. To allow the occurrence of weeds and by doing so to "produce" ecological goods and services, the application of pesticides and the implementation of other weed reducing measures has to be minimized or abandoned. At the same time the above stated negative site effects increase and generate additional production costs. This loss of income is caused by husbandry measures that exceed cross compliance regulations and thus can be compensated by agri-environmental programs.

Table 1. Mean number of species of the weed associations of the regional district Bad Doberan and of the synonym associations of the regional district Northeim.

Bad Doberan	**mean no. of species**	**Northeim**	**mean no. of spec.**	**location**
Spergulo arvensis-Chrysanthemetum segetum	22 species per 25 m^2	*Lycopsietum arvensis*	22	summer crop and root crop community of acid and clayey sandy soils, good nutritive base
Sclerantho annui-Arnoseridetum minimae	19 species per 50 m^2	not in Northeim		highly acid, sandy soils, low in nutrients, relatively species-poor
Papaveretum argemones	24 species per 25 m^2	*Papaveretum argemones*	25	obligatory winter crop community with typical spring aspect, sandy soils, low water supply
Aphano arvensis-Matricarietum chamomillae	17 species per 25 m^2	*Aphano-Matricarietum chamomillae*	25	winter crop community of sandy to heavy clay, good nutritive base
not in Bad Doberan		*Holco-Galeopsietum*	27	grain and root crop community of siliceous locations in the low mointain range
Galeopsietum speciosae	27 species per 50 m^2	*Chenopodio-Oxalidetum fontaneae*	24	sommer crop and root crop community of fresh to moist, nutritive, soils, rich in humus, indicator species for moisture
Euphorbio exiguae-Melandrietum noctiflori	29 species per 50 m^2	*Papaveri-Melandrietum noctiflori*	28	species rich grain-winter crop community of limy, clayey, silty, and recondite soils with good nutrient and water supply
not in Bad Doberan		Caucalido-Adonietum flammeae	29	species rich grain-winter crop community on summerwarm locations of the limy hill country and highlands, moist
		Kixietum spuriae	24	as above, dry
Veronico persicae-Lamietum hybridi	27 species per 30 m^2	*Thlaspio-Veronicetum politae*	31	summer crops community with heat indicator species on basic to limy and nutritive clay
		Thlaspio-Fumarietum officinalis	26	
not in Bad Doberan		Mercurialietum annuae	29	root crop community of loess soils, high demands on nutrition and heat and water balance

Berg et al. 2004; Preising et al. (1995) in Bertke (2004)

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The relative merits of field and boundary habitats for conservation biocontrol

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Abstract: Densities of boundary overwintering generalist predators within fields were estimated from their overwintering densities within such features. Their density was lower than that for those found emerging within fields, but numbers peaked in May compared to July for field overwintering species. Exclusion studies revealed that aerially dispersing beneficial invertebrates alone provided effective cereal aphid control although ground dispersing predators contributed to a small extent. Widening field margins had no impact on cereal aphid control.

Key words: generalist predators, beetle banks, biological control, IPM, Carabidae, Staphylinidae

Introduction

Conservation biocontrol has focussed on the provision of margin overwintering sites or enhancement of floral resources. Estimates of generalist predator densities within boundary vegetation in winter vary considerably (Andersen 1997; Collins et al. 2003; Thomas et al., 2000). These taxa invade fields in spring, however, overwintering sites may also provide attractive summer foraging resources constraining dispersal (Thomas et al., 2000). Consequently, beneficial invertebrates are often most abundant close to field boundaries declining with distance into the field. Their density is dependent on the ratio of field boundary to field area. Many species utilise the floral resources within margins but the extent to which their densities can be increased remains unknown. The margins also support Aphididae and their associated parasitoids both of which reinvade crops in spring. However, many of the most abundant generalist predator species overwinter within fields, predominantly as larvae while some Carabidae and Araneae may occur on the soil surface throughout the year. These groups are most affected by the farming practices and the conditions created. For these taxa there have been few attempts to manipulate their numbers by modifying their habitat even though they can occur at high densities.

The effectiveness of beneficial insects also depends on their phenology in relation to that of the pest. The most effective control is gained when beneficial insects are present early on in the pest's population development thereby preventing damage thresholds from being attained. In this paper the relative abundance of beneficial insects originating from margin habitats will be compared to those remaining year-long within fields. Their value for pest control was then compared using exclusion cages in habitats in fields with and without wide field margins.

Materials and methods

The density of generalist predators (Carabidae and Staphylidae) within fields was extrapolated from their overwintering densities within field boundaries using the maximum densities from three studies (Andersen 1997, Thomas et al., 2000; Collins et al., 2003). Densities were calculated for 5-20 ha square fields surrounded on all sides by either 2 or 6 m margins. The density of Carabidae and Staphylidae overwintering within fields was estimated from season-long emergence trapping conducted across two fields using a grid of 86 or 114 trapping locations as part of the "3D Farming project" (Holland et al., 2005). Also within this project the relative abundance of boundary and field overwintering generalist predators was compared, based upon pitfall trapping across six fields on eight week-long trapping occasions using a grid of 973 trapping locations. In the "Re-bugging the system project" levels of biocontrol were measured using different types of 1m^2 exclusion cages similar to those used by Schmidt et al. (2003). Four exclusion methods were used: 1. Control (includes netting to reduce wind & rain); 2. Ground predator exclusion (includes pitfall traps, spider removal and netting to reduce wind & rain); 3. Aerial predator exclusion; 4. Ground & aerial predator exclusion (includes pitfall traps & spider removal). Cages were infested with 500 *Sitobion avenae* and their numbers monitored. Two replicates of each exclusion cage were established in transects at 20 and 80 m from the margin. Five fields with standard margins (ca. 1-2 m wide) and in five with 6 m wide flower rich margins were used.

Results and discussion

The density of Carabidae and Staphylinidae originating from the field margins were frequently lower than those that overwintered within fields (Fig. 1). The difference in their numbers for fields with 2 and 6 m wide margins became less with increasing field size. Moreover, approximately a third of Carabidae and half the Staphylinidae may remain within field margins during the summer (Thomas et al., 2000), therefore the value of field boundaries as overwintering sites may have been overestimated.

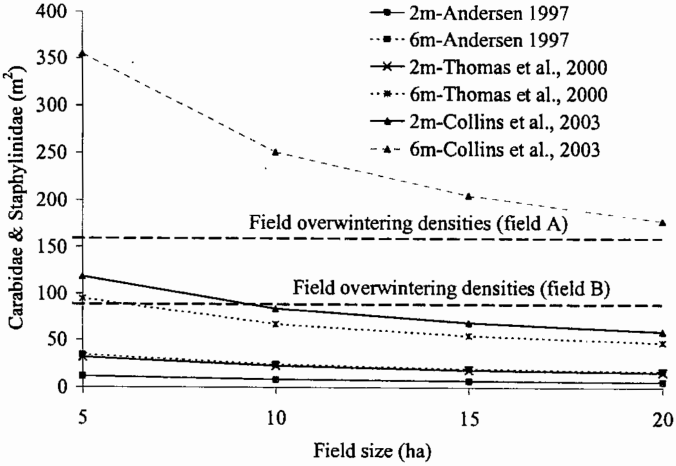

Figure 1. Predicted abundance of boundary overwintering Carabidae and Staphylinidae within fields with varying margin width compared to field overwintering densities of these two families for two fields (Holland, unpublished).

The pitfall trapping across six fields revealed that those species originating from the margins peaked earlier in the year but were again less numerous compared to those emerging from within the fields (Fig. 2). This, however, did ensure that a continuum of generalist predators was maintained throughout the growing season. Numbers of boundary-overwintering species may have been underestimated because they are less easily captured by pitfall trapping compared to the larger field-overwintering species. Field-overwintering invertebrates were highly abundant in summer and their management requires consideration. Certain tillage operations are considered to be harmful, especially ploughing and rotary cultivations, and therefore a switch to non-inversion tillage can be beneficial (Holland & Reynolds, 2003). Of the environmental factors known to influence invertebrate survival, weed cover and soil moisture are considered the most important. Weed cover may be manipulated through herbicide inputs but obtaining acceptable levels is difficult and invertebrate species differ in their requirements. Soil moisture is important because oviposition sites are selected based upon moisture levels and these may subsequently impact on overwinter survival. Soil moisture levels are managed to some extent by farmers though changes in drainage, cultivations and organic matter levels, however, further research on their relationship with beneficial invertebrates is needed if they are to be manipulated for this purpose.

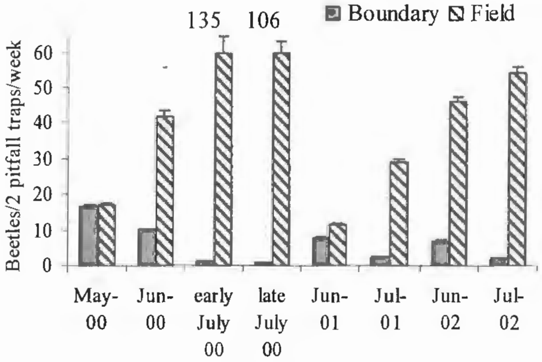

Figure 2. Relative numbers of boundary and field overwintering beetles per pair of pitfall traps.

Where there was exclusion of ground and aerially active predators/parasites the numbers of cereal aphids increased 100-fold in six weeks. In the control and where aerial flying predators were allowed access the aphids were almost completely absent (Fig. 3.). There was no difference in the total level of aphid control between fields with or without 6 m wide flower-rich margins. Numbers of aphids within the cages were similar at 20 and 80 m from the field margin.

The exclusion studies demonstrated that the aerially dispersing invertebrates provided complete aphid control while the contribution from epigeal predators was small in comparison. Using the same technique Schmidt et al. (2003) found that where there was aerial exclusion aphid numbers were 70% higher than the controls, with 1.0 and 0.58 aphids per shoot respectively. Widening the margins had no effect, probably because of immigration by aerially dispersing predators and parasitoids from outside the study area. A combination of boundary and field management practices are needed to ensure a broad suite of beneficial invertebrates are present for pest control throughout the growing season.

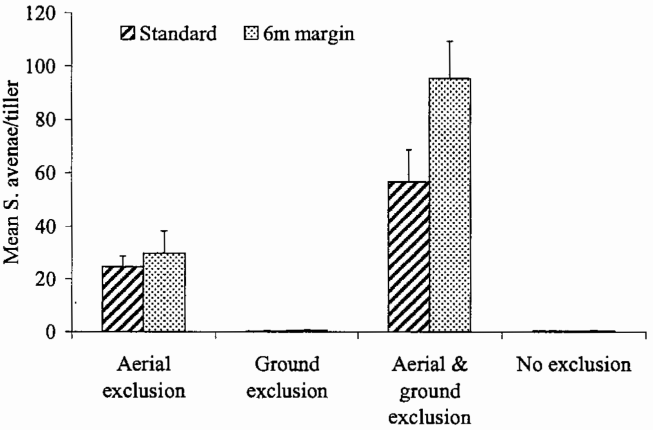

Figure 3. Mean *S. avenae* per tiller within exclusion cages adjacent to standard and 6m wide margins.

Acknowledgements

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Rotational fallows in support of functional biodiversity

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Abstract: Rotational fallows could diversify cereal-dominated crop rotations and promote farmland biodiversity, but might also initiate weed and pest problems. In this study, various rotational fallows were compared from the viewpoint of pest populations and their natural enemies.

Six green fallow types were included in a field experiment comprising: 1) duration of fallow (1 or 2 years), 2) establishment method (undersown or not undersown) and 3) seed mixture (*Trifolium pratense - Festuca pratensis* or *Agrostis capillaris - Festuca ovina*, including *Phleum pratense* in both mixtures). In addition, spring barley and spring barley stubble were included as references. The canopy insects were collected with yellow sticky traps and epigeal arthropods were sampled with pitfall traps.

In fallows sown during the previous year, spider abundance was significantly higher than in first year fallows and in spring cereal fields. However, ground beetle abundance was similar across fallow types and cereal. Cereal pests were more abundant in first year green fallows and in spring barley than in fallows sown in the previous year. Generally, first year fallows did not differ clearly from cereal fields as habitats for pests and their natural enemies and vegetation structure (total biomass) was more important than plant species richness. The results suggest that even a short-term fallow sown with a simple seed mixture can encourage populations of generalist predators.

Key words: insects, spiders, natural enemies, pests, fallow, set-aside, diversity

Introduction

The diversity of agricultural landscapes has decreased due to decline in the area of semi-natural grasslands and field margins and adoption of monocultures. These changes have been detrimental for species diversity of farmlands. Inclusion of short-term fallows in cereal-dominated crop rotations could diversify agricultural landscapes. While such rotational fallows are beneficial for biodiversity (e.g. Corbet 1995, Van Buskirk & Willi 2004), they might initiate weed (Salonen & Hyvönen 2006) and pest problems (Hancock et al. 1992). On the other hand, a more diverse and permanent vegetation could strengthen the populations of natural enemies by providing food sources and hibernation sites for predators and parasitoids (e.g. Landis et al. 2000).

In this study, populations of pests and polyphagous predators in various rotational fallows were studied from the viewpoint of functional biodiversity.

Material and methods

Field experiment

A 4-year (2003-2006) field experiment was established in Jokioinen, in southern Finland (60°49'N, 23°28'E), to study the effects of various rotational fallows on biodiversity. Six green fallow types were included, comprising the following factors: 1) duration of the fallow (1 or 2 years), 2) establishment method (undersown or not undersown) and 3) seed mixture (*Trifolium pratense - Festuca pratensis* or *Agrostis capillaris - Festuca ovina*, including

Phleum pratense in both mixtures). In addition, spring barley and non-cultivated spring barley stubble were included as references (Table 1). The experiment was conducted on clay soil as a was 0.3 hectares (44 m x 66 m).

Table 1. Establishment of the set-asides in the experiment.

Type of set-aside	**Seed mixture / Crop**	**Sowing year**
Cereal (spring barley)	Spring barley	2004
1-year stubble fallow	Spring barley	2003
1-year fallow mixture 1	*Agrostis capillaris* L., *Festuca ovina* L.	2004
1-year fallow mixture 2	*Trifolium pratense* L., *Festuca pratensis* Huds	2004
Undersown 2-year fallow mixture 1	*Agrostis capillaris* L., *Festuca ovina* L.	2003
Undersown 2-year fallow mixture 2	*Trifolium pratense* L., *Festuca pratensis* Huds	2003
2-year fallow mixture 1	*Agrostis capillaris* L., *Festuca ovina* L.	2003
2-year fallow mixture 2	*Trifolium pratense* L., *Festuca pratensis* Huds	2003
	Phleum pratense in both mixtures	

Sampling

In 2004, the canopy insects were collected with yellow sticky traps and epigeal arthropods were sampled with pitfall traps. One sticky trap and three pitfall traps were placed in the centre of each plot and insects were collected during a one week period three times (in June, July and August). The pitfall traps were plastic cups with a diameter of 9.5 cm and depth of 10 cm. The trapping liquid was concentrated NaCl solution (300 gl^{-1}). Total biomass (air-dry weight) of sown and unsown plants and the number of unsown plant species were assessed from four 0.25 m^2 (0.5 m x 0.5 m) sample quadrats on each plot in late August.

The data of Araneae and Carabidae abundances as well as biomass of plants were analysed with ANOVA and were either square root (Araneae and Carabidae) or log (x+1) – transformed (plant biomass) before analyses. Non-parametric Friedman's test was applied for the analyses of the data of *Phyllotreta* and *Oscinella* abundances as well as the number of plant species.

Results and discussion

Pest numbers were low in the sticky traps and the catch was dominated by Diptera species (over 95% of all insects). In general, total insect catches in the vegetation were lower in first year fallows than in stubble and second year fallows. However, cereal pests, such as *Oscinella frit* and *Phyllotreta undulata*, were more abundant ($P<0.05$) in first year green fallows and in spring barley than in fallows sown in the previous year (Fig. 1a).

Contrary results were recorded for spiders, the dominant group of natural enemies in pitfall traps. Their numbers were significantly higher ($P<0.001$) in stubble and 2-year fallows than in first year fallows and in spring cereal (Fig. 1b). Abundance of ground beetles (Carabidae) did not differ among fallow types and cereal (Fig. 1b). An increase in the proportion of the natural enemies compared with pests is in accordance with the results of previous studies (Corbet 1995).

Although vegetation diversity is important for arthropods, their abundance is not a simple function of plant species richness (Perner et al. 2005). This was evident also in this experiment: permanence of habitat and abundance of vegetation (biomass) was more important for spiders than was plant species richness (Fig 1b & 1c). For many insects and spiders the vegetation structure is more important than the species richness as such. Previous

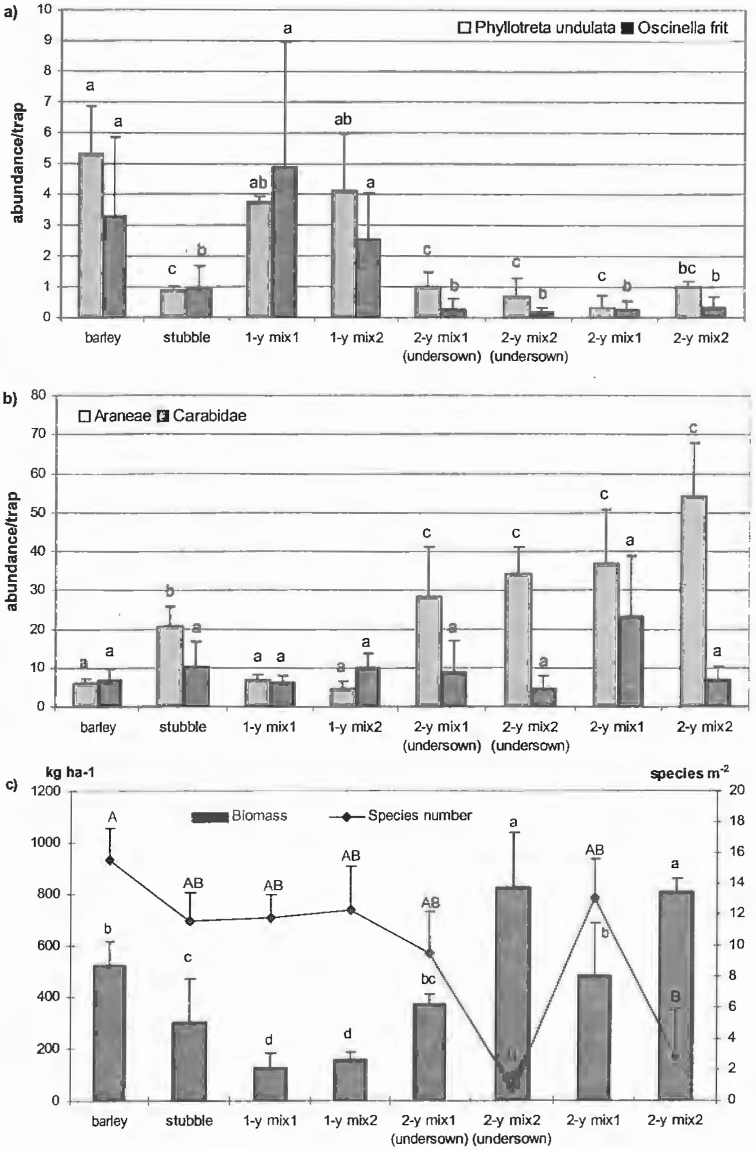

Figure 1. Abundances (Mean, SD) of a) pests (*Phyllotreta undulata* and *Oscinella frit*) in yellow sticky traps, b) natural enemies (Araneae and Carabidae) in pitfall traps and c) total biomass (kg ha^{-1}) and number of unsown plant species m^{-2} in different fallow treatments. Means with the same letter not significantly different (mix1= *Trifolium pratense - Festuca pratensis - Phleum pratense*; mix2= *Agrostis capillaris - Festuca ovina - Phleum pratense*).

studies showed even simple permanent grasslands to be able to maintain a diverse community of leafhoppers (Huusela-Veistola & Vasarainen 2000) and large spider populations (Huusela-Veistola 1998) in contrast to butterflies and pollinators that require a diversity of flowering plants (Steffan-Dewenter & Tscharntke 1997). In the present experiment, the vegetation was also sown with a species poor seed mixture.

Conclusions and outlook

In this study only one aspect (biological control and plant protection) of functional biodiversity was studied. The risk of pest problems near the rotational fallows was low. In contrast, natural enemies, such as spiders, were more abundant in rotational fallows sown in the previous year than in cereal fields. Although no significant differences in abundance of ground beetles were detected, rotational fallows may provide important refuge habitats.

Because of the various species requirements numerous habitats are needed if biodiversity is to be increased or maintained. At the landscape level, the proportion and location of non-crop habitats (including green or stubble fallows) may be important factors for key ecosystem services, such as biological pest control. Since the proportion of most pest insects decreases, whereas the proportion of natural enemies increases during the succession of set-aside areas (Corbet 1995), long-term fallows may be even better than short-term fallows for plant protection.

In Finland, the regional concentration of cereal production and increase in farm size have recently reduced crop rotations. For this reason diversification of crop rotations with rotational fallows has been proposed to be included in the new agri-environmental support scheme for 2007-2013 in Finland.

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The role of ecological compensation areas on spider assemblages in crop fields in Switzerland

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Abstract: In Switzerland, ecological compensation areas (ECA) are introduced in the cultivated landscape to promote biodiversity. Although ECA are known to enrich the regional arthropod diversity and influence the arthropod diversity of arable fields at immediate vicinity, little is known about their effect at landscape scale. In windows of three sizes, the proportion of ECA was recorded around arable fields. Correlations between the proportion of ECA and characteristics of spider assemblages (richness, activity density, characteristic and accompanying species) were calculated. None of the characteristics were significantly correlated with the proportion of ECA at any scale. We assume that the proportion of ECA in the arable landscape is to low to significantly correlate with the characteristics of spider assemblages investigated.

Key words: arable land, Spiders, ecological compensation areas

Introduction

In Switzerland, from 1993 onwards, one of the measures for farmers to provide ecological services in order to qualify for direct payments was the introduction of ecological compensation areas (ECA) within the utilised agricultural area. The Swiss agri-environmental programme requires that participating farmers have to convert 7 % of their farmland to ECA. The range of ECA encompasses extensively managed and low intensity meadows (restricted fertilisation, late mowing), humid meadows used for litter production, wild flower strips, fruit trees in traditional orchards, hedgerows and groves.

Spiders are important generalist predators for natural pest control in agricultural fields (e.g. Riechert & Lockley, 1984). However, agricultural fields are highly disturbed habitats which present a number of challenges to the organisms living there. Although some agrobiont species (e.g. *Oedothorax apicatus, Erigone atra*) are able to survive in arable fields from one year to the other (Duffey, 1978), most of them have to re-colonize the fields every year. In this connection, natural and semi-natural ecosystems in the arable landscape are important refuges and sources for field re-colonisation (e.g. Luczak, 1979). In particular, less disturbed habitats in the immediate vicinity of the fields largely contribute to the diversity of spider assemblages and individual densities found in the fields (e.g. Toth & Kiss, 1999; Frank & Nentwig, 1995). At landscape scale, studies have revealed a positive influence of semi-natural habitats on spider species richness inhabiting crop fields (Schmidt et al., 2005; Topping & Sunderland, 1994). In Switzerland, ECA are supposed to generally enhance the biodiversity in the cultivated landscape. Jeanneret et al. (2005) found that ECA contain different spider assemblages than agricultural fields. However, the influence of the proportion of ECA at the landscape scale on spider assemblages inhabiting arable fields has not yet been investigated.

We addressed the following questions: (i) What is the influence of the proportion of ECA in the landscape at a medium scale (200 to 600 m) on the spider assemblages in crop fields? (ii) Are there specific spider species that are influenced by the proportion of ECA?

Material and Methods

The study was carried out in the arable region of the Rafzerfeld (20 km NW of Zurich, Switzerland). The region consists of arable land (47%), grassland (5%), forests (20%), gravel pits (11%), and special cultures (6%). Four ECA habitat types, usually small areas of approximately 400 m^2, can be found, namely extensively managed and low intensity meadows, hedgerows and wild flower strips. Spiders were collected in 19 conventionally managed arable fields (3 winter wheat, 6 sugar beet, 4 ley and 6 corn fields) with 3 pitfall traps (10.5 cm diameter) per field, during the first 3 weeks of May and last 2 weeks of June in 2003. The 3 pitfall traps and 5 weeks of sampling per site were pooled for the analysis. We defined the number of individuals caught as "activity density". The proportion of ECA around the crop fields was calculated for three window sizes, i.e. 200x200m, 400x400m and 600x600m.

Correlations between several characteristics of the spider assemblages caught in the crop fields (Table 1) and the proportion of ECA at each of the three scales were calculated (Pearson *r* correlation coefficient).

Table 1. Characteristics of spider assemblages captured in crop fields and used in correlations with ECA proportions (Pearson *r*). S = Number of species; A.d. = Activity density; %S/N = Proportion of species and individuals.

Overall	S; A.d.
Characteristic crop field and ECA species	S; A.d.; %S/N
Accompanying crop field species	S; A.d.; %S/N
Most abundant species	A.d.
Rare species	S; A.d.; %S
Linyphid and Lycosid species	S; A.d.

To determine the characteristic and the accompanying species, we analysed spider assemblages captured with the same method as for crop fields in 24 typical ECA habitats of the region (10 wild flower strips and 14 extensively used meadows). Species were defined as "characteristic crop field species" if more than 2/3 of the total captured individuals in both crop fields and ECA were found in crop fields. Similar the "crop field accompanying species" are those with more than 1/3 of total individuals captured in crop fields. Hypothetising that ECA characteristic and accompanying species captured in crops may also be influenced by the proportion of ECA in the surrounding area, correlations were calculated for these species. Furthermore, the number of individuals of the most abundant species found in crops were analysed as well as the number and the activity density of rare species for Switzerland as defined by Pozzi et al. (1998). As an important part of the spider assemblages, furthermore linyphid and lycosid species were separately investigated.

Results and Discussion

Altogether, 4127 spider individuals belonging to 77 species were captured in the 19 crop fields (19 ± 6 species and 217 ± 102 individuals on average). The spider assemblages were largely dominated by the species that are usually found in arable fields across Europe (Blick et al., 2000), i.e. *Pardosa agrestis* (33.9% of the individuals), *Oedothorax apicatus* (26.6%), *Pardosa palustris* (8.7%), *Pachygnatha degeeri* (5.8%).

The ECA proportions in the three windows around the 19 crop fields are summarized as follows:
200x200m: 2.6% on average, minimum value = 0% and maximum value = 20.1%
400x400m: 3.0% on average, minimum value = 0% and maximum value = 15.1%
600x600m: 3.3% on average, minimum value = 0.3% and maximum value = 8.8%

On average, the proportion of ECA in the surroundings of the investigated fields is under the 7% level that has to be reached at the farm level. This means that ECA are mostly not introduced around the crop fields investigated but elsewhere on the farm area, probably in less productive parts. Nevertheless, the minimum and maximum values denoted a steep gradient.

None of the spider assemblage characteristics presented in Table 1 was significantly correlated (Pearson *r*; $p < 0.05$) with the proportion of ECA in the landscape at any scale.

The assumption that the activity density of species which are chararacteristic for crops and also occur in high abundance in ECA (e.g. *Pardosa agrestis*, *Oedothorax apicatus*, *Meioneta rurestris*) would be influenced by the share of ECA in the surroundings could not be verified. Moreover, the activity density of accompanying species of crops also occuring in ECA (e.g. *Erigone dentipalpis*, *Lepthyphantes tenuis*, *Erigone atra*), were also not correlated with the proportion of ECA at different scales. In addition, characteristic species of ECA (e.g. *Pardosa palustris*, *Pachygnata degeeri*, *Trochosa ruricola*) captured in crop fields were not more abundant in crop fields with a higher proportion of ECA in the surroundings. Similarly, the number of rare species and their activity density in crop fields (species also occuring in ECA) were not correlated with the proportion of ECA.

We propose two hypotheses to explain our results. It has been demonstrated that semi-natural habitats enhance the spider species diversity and abundance in arable fields at least when they occur in the immediate vicinity of the field (Luczak 1979; Toth & Kiss, 1999; Frank & Nentwig, 1995). This phenomenon may mainly be important in spring after overwintering. Spiders most likely spend the winter in the adjacent surroundings of the fields (Wiedemeier & Duelli, 1996). ECA, dispersed in the landscape forming 3% of the cultivated land on average around the crop fields, cannot play this role at large scale. In comparison to the results obtained by Schmidt et al. (2005) showing a significant positive correlation between the proportion of non-crop habitats and the spider species richness in crop fields, we argue that accounting for the whole non-crop area around the field including forest and grassland, the study of Schmidt et al. (2005) was based on a much stronger gradient, reaching values of up to 70% non-crop area in the surrounding of some of the crop fields. Thus, the most relevant conclusion from the missing correlation between the ECA proportion and the characteristics of the spider assemblages of crop fields should be that that the proportion of ECA is too low to influence the spider species richness and activity density in crop fields at the scales investigated.

A second, contrasting hypothesis can be formulated, i.e. the present proportion of ECA has already increased the species pool of the region so that the level in crop fields has already reached an optimum for that proportion. This could also explain that no differences between the spider assemblages of different crop fields could be detected regarding the proportion of ECA in their surroundings. We cannot test the validity of this hypothesis because there is no control landscape in Switzerland where ECA would be absent but comparisons could be made with past and additional data from other studies.

Still, regardless which hypothesis is valid, we conclude that the ECA proportion in the landscape should increase to influence spider assemblages found in crop fields. Further investigations, coupling field data with modelisation, should be made to determine the level at which the ECA proportion has an influence on the spider assemblages of crop fields.

In an arable farming region, the immediate vicinity of the field, i.e. the field margins, managed as ECA or not, probably play the most important role in determining the differences in spider assemblages between crop fields (next to farming practices). Indeed, spider species colonising crop fields from larger distances by ballooning are able to easily reach every field in the landscape and thus, form the basic agrobiont assemblage found in every field. In this context, ECA may contribute to enrich the global basic agrobiont assemblage but will not predominantly influence its distribution. Rather, ECA may influence the proportion of species that are not commonly distributed among the crops, e.g. species with low dispersal abilities. Our results suggest that in our region, ECA have not reached a sufficiently high proportion to play this role. However, it must be emphasized that ECA enhance the regional diversity because they contain species that cannot be found in agricultural fields (Jeanneret et al., 2005), thus contributing to the regional biodiversity.

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Effects of field management, environment and landscape context on vascular plant species diversity in managed grasslands

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Abstract: Decline of grassland diversity throughout Europe within the last decades is threatening biological diversity and is a major conservation problem. There is an urgent need to understand the ecological mechanisms that control vascular plant species richness and composition in managed grasslands. In this study, 117 grasslands were sampled using standardized methods and explanatory variables were recorded for each grassland site, reflecting field management, site-specific environmental conditions and the surrounding landscape context. The impact of landscape variables on local plant species diversity was analysed on two different spatial scales (250 m and 500 m) to account for processes acting at larger scales. To determine the relative importance of these sets of explanatory variables on plant species diversity in managed grasslands, existing variance partitioning methods were used to estimate which proportion of the total variation is explained by each of the three sets of variables exclusively and which proportions are attributable to the covariance between them. In general, variance partitioning by means of multiple linear regression and canonical redundancy analysis found the amount of total explained variation to be much higher for species richness data than for species composition data. While species richness in grasslands was primarily controlled by local field management variables, species composition was mostly affected by both field management and environmental variables. Moreover, the results revealed that the landscape surrounding each grassland site had a low impact on plant species diversity. From our findings we conclude, that in particular a reduction of nitrogen fertilisation and the consideration of local site conditions can help to establish efficient agri-environment schemes for the conservation of biodiversity.

Keywords: grassland, agri-environment scheme, vascular plant species diversity, variance partitioning

Introduction

Conserving biodiversity and the services it provides is an urgent task for our society. Meanwhile, a variety of agri-environment schemes have been applied in European countries but the efficiency of these agri-environment schemes has been questioned (Kleijn et al., 2001). In order to enhance the efficiency of management measures prescribed in agri-environment schemes, there is an urgent need to understand the underlying mechanisms that determine vascular plant species diversity in grasslands.

It is well established that species diversity in grasslands generally decreases due to high nitrogen fertiliser applications (Jacquemyn et al., 2003). Besides field management intensity, recent work showed that plant species richness varies in response to topography-related environmental factors such as site-specific solar radiation and slope angle (Pykälä et al., 2005). Furthermore differences in local plant species diversity may be caused by ecological processes acting at larger spatial scales and recently published studies focused on the effects of landscape context on local plant species diversity (Söderström et al., 2001).

The specific objectives of this study were thus: (i) to determine the relative importance of field management, environmental and landscape variables on local plant species richness and composition and (ii) to examine if the relative importance of landscape variables on local plant species richness and composition differs at different spatial scales.

Material and methods

The research area and sampling design

All field research has been carried out within the rural district of Northeim in Lower Saxony (Germany) with a total area of approximately 1260 km^2. Grassland vegetation was recorded in two field surveys in May/June in 2002 and 2004. In total we sampled 117 managed grassland sites at random, covering a complete gradient from agriculturally improved, species-poor grasslands to semi-natural, species-rich grassland that have not experienced a history of agricultural improvement. Edge effects were avoided by excluding a 10 meter wide buffer zone around the field margin. In each grassland site, three circular sample plots of 12.6 m^2 (radius of 2 m) were established and species richness was calculated as the cumulative number of all vascular plant species within three sample plots. Frequency of occurrence, as determined in three sample plots per grassland site, was used as a measure of species abundance and was applied in ordination methods.

Explanatory variables

To record relevant information about management intensity, all landowners of the investigated grassland sites were interviewed using a standardized questionnaire. Applied nitrogen fertilisation per hectare and year included mineral N, farmyard manure or liquid manure.

The set of site-specific environmental variables used in this study was comprised of topography-related environmental variables as well as soil-related environmental variables. The following topography-related quantitative explanatory variables measured from all grassland sites were included in the study: elevation, slope angle and daily solar radiation sum. Additionally the environmental variable soil quality, based on the estimate of value of land for agricultural production, was spatially derived using detailed vector-based digital soil map data.

The landscape surrounding each individual grassland site was analysed within a radius of 250 m and 500 m. Due to relatively short geographical distances between grassland sites and to avoid overlap of radii, larger spatial scales were not within the scope of this study. For both spatial scales we calculated the percentage of grassland and arable land, the habitat type diversity (Shannon-Wiener index) and the mean perimeter-area ratio. Within the radius of 500 m one grassland site was omitted because of missing data at the border of the research area.

In all statistical analyses, field management, environmental and landscape factors were treated as quantitative numeric variables, while management regime (meadows, pastures and mowed pastures) was treated as a qualitative nominal variable.

Data analysis

We used quantitative variance partitioning methods to investigate species-environment relationships and to estimate the independent contributions of different sets of explanatory variables, as well as the covariance between them (Borcard et al., 1992). To analyse effects on plant species richness among the three sets of explanatory variables, linear regression models with partial regression were used. The variation in species composition was analyzed with linear-based ordination methods such as canonical redundancy analysis (RDA) and partial redundancy analysis (partial RDA) using direct gradient analysis techniques provided by the software package CANOCO version 4.5 (ter Braak and Smilauer, 2002). Prior to analyses the distributional properties of the response and explanatory variables were checked for normality and variance homogeneity and, where appropriate, log-transformed to meet the requirements of parametric analysis. Proportion data were arcsine square-root transformed.

Results and discussion

Partitioning the variance of species richness data

Overall, plant species richness in managed grasslands was best explained by explanatory variables reflecting field management followed by environmental site conditions. Landscape variables showed significant effects on species richness only within the radius of 500 m and explained much less variance than management and environment (Table 1). The most consistent field management effect on plant species richness was determined by the negative impact of nitrogen fertilization.

Table 1. Importance of explanatory variables ($P < 0.05$) in linear regression models (species richness) and RDA models (species composition) for vascular plant species in managed grasslands. The amount of explained variation (R^2 in %) is given for each model. Directions of association (- or +) and *P*-levels for significant variables are shown. SQ = Soil quality; SLOPE = Mean slope angle (deg); ELEV = Mean elevation (m a.s.l.); RAD = Mean solar radiation sum (kWh/m^2); N = Nitrogen fertilisation (kg N ha^{-1} $year^{-1}$); PG = Percentage of grassland in surrounding landscape (%); PA = Percentage of arable land in surrounding landscape (%); MPAR = Mean perimeter-area ratio in surrounding landscape.

	Environmental models			**Management models**			**Landscape models**		
Spatial extent	**Variable**	***P*-level**	**R^2**	**Variable**	***P*-level**	**R^2**	**Variable**	***P*-level**	**R^2**
Species richness									
250 m	SQ	0.001 (-)	26.5	N	0.001 (-)	30.7	-	-	-
	SLOPE	0.003 (+)		PASTURES	0.001 (+)				
500 m	SQ	0.001 (-)	26.6	N	0.001 (-)	30.9	PG	0.016 (-)	8.6
	SLOPE	0.004 (+)		PASTURES	0.001 (+)		PA	0.037 (-)	
Species composition									
250 m	ELEV	0.001	13.0	N	0.001	9.8	PA	0.004	5.3
	SLOPE	0.001		MEADOWS	0.001		PG	0.005	
	RAD	0.001		PASTURES	0.017		MPAR	0.034	
	SQ	0.012							
500 m	ELEV	0.001	13.1	N	0.001	9.7	PA	0.002	6.0
	SLOPE	0.001		MEADOWS	0.001		PG	0.006	
	RAD	0.001		PASTURES	0.016		MPAR	0.002	
	SQ	0.017							

In general, pure management variables accounted for more of the variation explained than environmental and landscape variables (Table 2). Total variation explained in species richness by all three sets of explanatory variables was highest for the radius of 500 m (42.1 %).

Partitioning the variance of species composition data

Redundancy analysis decomposed the total variation in species composition data into variation explained by environmental, field management and landscape sets of variables, and their shared components (Table 2). All models showed significant effects on species composition and the partitioning of the variation revealed that only 3.4 % of the total variance in species composition was solely explained by landscape variables at both spatial scales after partialling out all other variables.

Table 2. Variance partitioning among pure and combined effects of environment (E), management (M) and landscape (L) sets of explanatory variables explaining species richness and species composition in grasslands. The amount of explained variation (R^2 in %) is given for each component. *P*-levels are given in brackets.

	Pure components			**Shared components**				**Unexplained**
	E	**M**	**L**	**E+L**	**E+M**	**M+L**	**E+M+L**	
Species richness								
250 m	9.4 (0.001)	13.6 (0.001)	-	-	17.2	-	-	59.8
500 m	7.2 (0.002)	12.8 (0.001)	2.0 (ns)	2.0	13.5	0.7	3.9	57.9
Species composition								
250 m	8.5 (0.001)	6.3 (0.001)	3.4 (0.001)	1.1	2.7	0.1	0.7	77.2
500 m	8.3 (0.001)	6.2 (0.001)	3.4 (0.001)	1.4	2.3	0.0	1.2	77.2

Discussion

The pure and shared variance decompositions provided a comprehensive picture of the relative importance of field management, environmental site conditions and landscape variables on species richness and composition in managed grasslands. In general, variance partitioning found the amount of total explained variation to be much higher for species richness data than for species composition data. This suggests that the mechanisms controlling species composition in managed grasslands are more complex compared to species richness. Our results support the view that plant species are most affected by local field management intensity as well as environmental site conditions which have been shown to be key factors in determining species diversity (Jacquemyn et al., 2003; Pykälä et al., 2005). Even though landscape variables showed pure significant effects on species composition at both spatial scales the overall effect of landscape variables on species diversity in managed grasslands is low.

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Structures of projects on nature conservation and their impact for subsequent activities – Practical experiences in arable regions

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Abstract: The attributes of interactions between corporative actors are crucial for the results of policy development and implementation processes.

Hence, also the characteristics of project structures of nature conservation projects have an impact on the outcomes of these projects. Based on the principles of the *network theory* and considering the projects of the project network *"Lebensraum Börde"* as examples it can be shown, that strong actors, a high degree of networking and the inclusion of influential self-interested pressure groups can enhance the success of nature conservation activities.

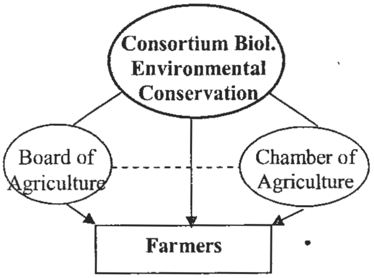
Key words: nature conservation projects, actor constellations, intensive arable regions, sown flowering strips

Introduction – the project network „*Lebensraum Börde*"

The project network *"Lebensraum Börde"* (Projektverbund "Lebensraum Börde" 2005) consists of five pilot projects, that develop and implement production-integrated nature conservation measures especially adapted to intensively used agricultural areas (the term "Börde" is used for these areas with fertile soils in Germany). The major focus of this research and testing work is on sown flowering strips as nature conservation measures in arable regions, that do not compete permanently against land in production and that prevent the danger of the establishment of problematic weeds on fertile soils through succession.

The five pilot projects have diverse structures and actor constellations. They created in different degrees capacities for subsequent nature conservation activities. How different the structure of nature conservation projects, based on the principles of the *network analysis* (Scott 2000), can be and how subsequent nature conservation activities - also in response to the characteristics of project structures - can be ensured, will be illustrated in this article, considering the 5 pilot projects of the project network as example.

How can nature conservation projects be structured?

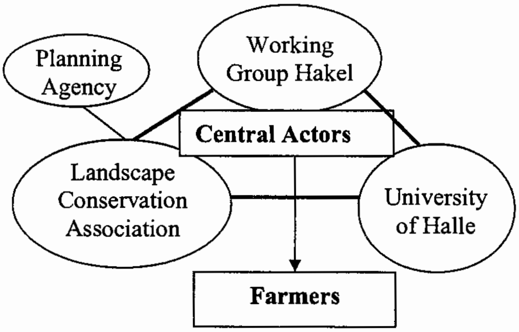


Project region "Soester Börde"

The project for enhancing biodiversity by extensified field margins and within field strips in the project region "Soester Börde" (in the *Bundesland* North Rhine-Westphalia) is mainly managed and carried out by one central actor – the consortium and registered association "Biological Environmental Conservation in the rural district Soest" (AG Biologischer Umweltschutz e.V., abbr.: ABU).

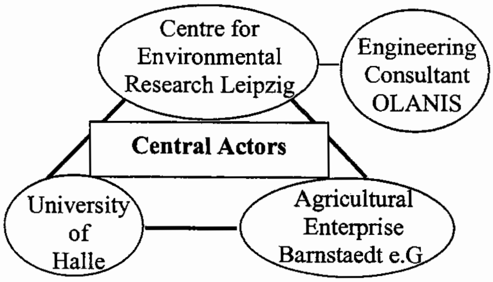
Beside these management and coordination tasks ABU is mainly responsible for scientific monitoring in the form of monitoring of goal species, but also in the form of acceptance studies and control of success. Furthermore ABU undertakes the development of the diverse production- integrated measures as well as public relations and presentation of project results. The main tasks of both secondary actors – the Board of Agriculture and the regional Chamber of Agriculture – are the conclusion of the contracts for nature conservation measures with farmers and the advisory service concerning these contracts.

Project region "Magdeburger Börde" (Hakel)



The nature conservation project in the project region Magdeburger Börde (in the *Bundesland* Saxony-Anhalt), that is situated in the European Bird Sanctuary Hakel, has a different constellation of central actors. The Landscape Conservation Association "Grüne Umwelt", a voluntary association of equal represented actors from agriculture, nature conservation and commune, manages and coordinates the project, whereas the university of Halle is responsible for the scientific support considering the monitoring of goal species. The Working Group Hakel has an allocative and advisory function in this project. It consists of representatives of relevant actors from the ranges of politics, administration, nature conservation, agriculture and hunting. One additional actor is personated by a planning agency, that is responsible for the digital acquisition, analysis and cartographic presentation of the nature conservation measures and their effects.

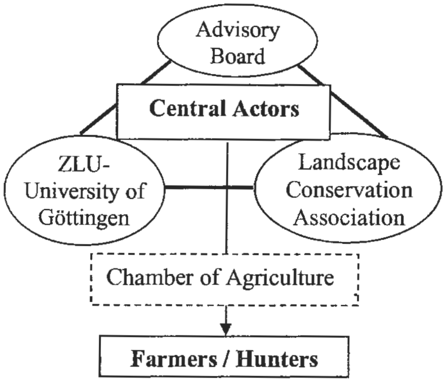
Project region "Querfurter Platte" (IUMBO)



The pilot project IUMBO (Integrative Realization of Method of Multicriteria Landscape Assessment and Optimization) in the *Bundesland* Saxony-Anhalt is an exception within the project network. Here agriculture is not only the target group of the nature conservation activities, but also in form of a single agricultural enterprise a central actor considering the development and implementation of the nature conservation measures. However, the agricultural enterprise has a considerable size of 6000 ha including almost the total arable area of three villages. It is run as cooperative enterprise that gives employment to local people in farming and all connected rural activities. The planning of these measures is based on the game theoretic planning method MULBO, that was developed in a former project by the project managing Centre for Environmental Research Leipzig (UFZ) and the engineering consultant OLANIS, and that tries to compromise between different landuse interests. The method was applied on the agricultural area of the mentioned farm for planning the required nature conservation measures.

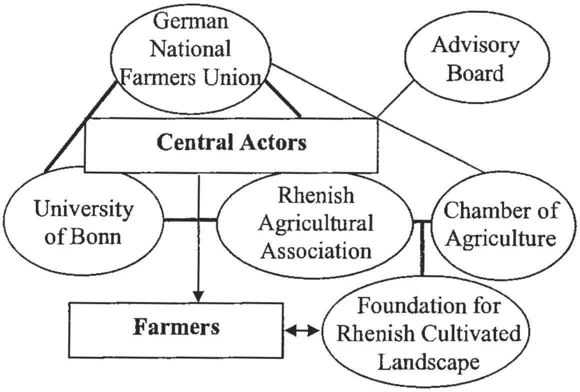
Afterwards these measures were optimised together with the farm manager. A scientific support considering the monitoring of goal species is given again by the University of Halle.

Project region "Wolfenbüttel"



The central actors of this project in the rural district Wolfenbüttel (in the *Bundesland* Lower Saxony) are the Landscape Conservation Association Wolfenbüttel and the Research Centre for Agriculture and the Environment (ZLU) at the University of Göttingen. The Landscape Conservation Association Wolfenbüttel is mainly responsible for fundraising, acquisition of participants, advisory service and public relation, whereas the ZLU escorts the project scientifically in certain fields. Additionally an advisory board consisting of representatives from agriculture, nature conservation, politics and administration has the task to enhance the acceptance of the project, to give professional advice, to determine the criteria for the allocation of subsidies and the subsidy level and to control the issue of funds. Beside these central actors a few more actors contribute to the success of the project. For instance the regional Chamber of Agriculture supports the project by informing and advising the farmers in its operational area.

Project region "Kölner Bucht"



The nature conservation project in the project region „Kölner Bucht" is comparatively affected by a multiplicity of central actors. The project managing German National Farmers Union (DBV), the most well-known German agricultural pressure group is a very strong actor available for the implementation of the project targets. The Institute for Phytogeography and Nature Conservation at the University of Bonn undertakes the scientific investigations within the project. It provides expertise with respect to nature conservation issues and has an intermediary function between agricultural and nature conservational problems. The Rhenish Agricultural Association (RLV) as the regional association of the German National Farmers Union (DBV), that incorporates approx. 95% of the farmers of the project region, provides the locally contact for the farmers. Together with the Chamber of Agriculture the RLV has established the Foundation for Rhenish Cultivated Landscape, that will give support to farmers and other interested landusers to plan and implement nature conservation measures also beyond the end of the project. An advisory board, consisting of representatives of the

Ministries of Agriculture and Environment, the Chamber of Agriculture, environmental associations, the DBV and scientific experts, has an advisory function for the project.

Conclusions - do project structures have an impact on the success of nature conservation projects?

Based on the principles of the *network analysis* (Scott 2000; Mayntz 1986) the central actors contributing to the development, the progress and the success of the project and their interlinkages were presented. The descriptions have shown, that nature conservation projects can consist of various actor constellations. These constellations can differ in the number and strength of their central actors, as well as in their weighting and degree of networking. For instance the weighting of agricultural and nature conservation actors is partly very different between the projects. To mention some examples the project in the region "Soester Börde" is dominated by one central nature conservation actor while the project structure in the "Kölner Bucht" is mainly characterised by several influential actors from the range of agriculture and agricultural administration. Relating to the degree of networking the project "Wolfenbüttel" can – mainly due to its comparatively high activity of the advisory board - be considered as a relatively high networked project. According to Mayntz (1986) and Scharpf (1997) the attributes of interactions between corporative actors are crucial for the results of policy development and implementation processes. Beside the design and the extent of successful implementation of nature conservation measures the degree of *capacity building*, that means the creation of capacities for subsequent nature conservation activities as one result of the project activities, can be diverse. Brendle (1999) refers to the *capacity building* as one essential feature of successful nature conservation projects.

It can be shown, that the cooperation of relatively strong agricultural actors in the pilot project "Kölner Bucht" has enabled the establishment of the Foundation for Rhenish Cultivated Landscape, that will promote similar nature conservation activities indefinitely.

Capacities for nature conservation are also created by enforcing the take-up of specific nature conservation measures into the catalogue of agricultural policy promotion instruments, as it was done with sown flowering strips, that has been taken-up into the agri-environmental program of Lower Saxony by initiative of the relatively wide networked project Wolfenbüttel.

It could also be established during the project work, that including influential self-interested pressure groups such as hunters can strongly enhance the success of the project, when for this target group so-called *win-win-situatiuons* are produced, that promote their own initiative to implement the project targets. In case of sown flowering strips or fallows it has become evident, that hunters are additionally fostering their implementation because of their promotional impact on wildlife.

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Field margin structure and vegetation composition effects on beneficial insect diversity at farm scale: a case study on an organic farm near Pisa (Italy)

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Abstract: The aims of this study were to determine (1) farm scale interactions most supportive to beneficial insect diversity (Coccinellidae, Syrphidae, Chrysopidae) and plant species richness, and (2) whether stimulation of beneficial insect diversity is compatible with weed control objectives. Farm scale field margin complex (FMC) quality (in terms of complexity and management) and vegetation composition were determined for 62 field boundaries on an organic farm near Pisa (Italy). Entomological diversity was determined in a selected number of FMCs. Results show that there was a negative correlation between FMC quality and weediness of the field boundary vegetation, whereas plant species richness increased with increasing FCM quality. Total insect density increased with weediness. Coccinellidae density was related to the presence of Chenopodiaceae and Malvaceae, and Chrysopidae density with the presence of Apiaceae. It can be concluded that there is no such thing as the ideal FMC structure. Complex and well managed FMCs promote a high plant species richness with a low percent of weed species, whereas simple FMCs with a more disturbed and weedy vegetation promote a higher beneficial insect diversity.

Key words: beneficial insects, weed species, field margin structure

Introduction

The autoregulatory capacity of agro-ecosystems forms an important aspect of organic farming and can be stimulated by cultural practices and landscape management. Appropriate crop rotations can help to maintain high soil fertility and to decrease dependency on pesticides, and semi-natural landscape elements can be managed to increase biodiversity. Agro-ecosystems with a high functional biodiversity, and thus with more functional groups, are generally thought to provide more ecosystem services than systems with a lower biodiversity (Clergue et al., 2005; Swift et al., 2004). Roschewitz et al. (2005) established that plant species diversity in agricultural landscapes was not only affected by management of single fields but also by heterogeneity of the surrounding landscape. However, if one is interested in ecosystem functioning, the presence of specific plant and animal species or groups of species might be more important than the general biodiversity level. More specifically, the presence of certain weed species in the field or in the field margins complexes may host alternate prey for beneficial insects (Norris & Kogan, 2000). For example, the natural predators of aphids, such as Coccinellidae, Syrphidae and Chrysopidae, find alternative food sources on *Urtica dioica* (Perrin, 1975). Crop and field margin management directed at the elimination of these species would therefore be detrimental to agro-ecosystem functioning.

The hypothesis of this study was therefore that field margin management directed at the decrease of disturbance and increase of plant species richness, carries along the risk of eliminating the necessary alternative host plants for beneficial insects. The aims of this study were to determine (1) farm scale interactions most supportive to beneficial insect diversity (Coccinellidae, Syrphidae and Chrysopidae) and plant species richness, and (2) whether stimulation of beneficial insect diversity is compatible with the weed control objectives.

Material and methods

The study area

The data used in this study were collected in 2003 on the organic beef farm (565 ha) "Tenuta di San Rossore", inside the Natural Park Migliarino - San Rossore - Massaciuccoli (4,770 ha), Tuscany, Italy. The Tenuta (estate) of San Rossore is extended east of the Tyrrhenian Sea, in an area included between the rivers Arno and Serchio, west of Pisa. More than 60% of the area is occupied by mixed deciduous and pine woods, whereas the remainder is characterised by dune and coastal vegetation, humid vegetation, constructions and agriculture. The organic beef farm follows the EU regulations for organic agriculture since 1997. The 565 ha of agricultural land is divided in two areas, 372 ha north of the Arno and 193 ha south of the Serchio. The Arno area is characterised by 310 ha of cereals, maize, pigeon bean and lucerne, and 62 ha of fast growing poplar plantations. The Serchio area has 141 ha of meadows, pastures and some lucerne whereas the remaining 52 ha are occupied by fast growing poplar plantations. About 120 adult cows and 600 calves are reared in the Serchio area.

Data sampling

For this research, only the Arno area was taken into account, consisting of 19 production units and 62 field margin complexes (FMCs). A production unit is defined as a continuous area with the same cropping history since 1997. The FMC is defined as the ensemble of all linear elements present between two cropped fields: pre-existing boundary, field margin strip (if present) and crop edge (Marshall & Moonen, 2002). The presence of all plant species in the entire pre-existing boundary, varying from 100 to 500 m, were recorded. Each species was attributed to one of the following five classes, where those species known to cause problems in the crop were defined as weeds: grasses, weedy grasses, dicotyledonous weeds, herbaceous dicots and woody species. Percent weediness of the vegetation was calculated. Beneficial insect sampling (Coccinellidae, Syrphidae and Chrysopidae) was performed by placing one chromotropic yellow sticky trap at about 2 m height in each of the eight randomly chosen FMCs on 4 June 2003. Traps were collected after 15 days and the number of beneficial insects was recorded. FMC integrity was characterised by eight easy to measure indicators: tree and shrub cover, width of FMC, width of the field margin strip, presence of a ditch or a fence, visual signs of FMC management and crop longevity on both sides of the FMC. All values were standardized on a 0 to 1 scale. The resulting Field Margin Complex Integrity Index (FMCII) can vary from 0 to 8, where 0 represents structurally poor and much disturbed FMCs and 8 structurally rich and well managed FMCs and it has been expressed as percent of maximum integrity.

Data analysis

Linear regression analysis was performed to establish if Field Margin Complex Integrity affects weediness and species richness of the FMC vegetation and consequently if these factors interact with beneficial insect density. Principal Components Analysis was performed to establish which plant families were characteristic of FMCs with high and low integrity and which plant families attract beneficial insects.

Results and discussion

The field boundary vegetation

In the 62 field boundaries 178 species were recorded belonging to 49 families with a species richness varying between 10 and 54 species per field boundary. Weediness varied between 32% and 88%. In the eight FMCs selected for insect sampling, species richness varied between 16 and 50 species and weediness between 43% and 76%.

Linear regression analysis

FMCs with a high value of the FMCII were characterised by elements mitigating disturbance originating from the cropped field and creating new niches. FMCs that were structurally poor and carried visual signs of disturbance had a lower plant species richness and a higher percent of weed species. At the same time, a higher plant species richness was correlated to a lower weediness of the field boundary vegetation. The same correlations were found for the eight FMCs selected for beneficial insect sampling. Beneficial insect density was not related to the FMCII, but it increased with increasing weediness of the field boundary vegetation. This correlation increased strongly when one outlier was removed. This FMC was structurally poor and disturbed, and had a high percent weediness but contrary to what could be expected, few beneficial insects (Table 1). This could be explained by the fact that the yellow trap was attached to the only tree present in the whole FMC.

Table 1. Linear regressions (Y = aX + b), correlation coefficients (r), number of samples (n) and P values for the Field Margin Complex Integrity Index (FMCII) and insect and plant diversity combinations. n = 62: all field boundaries, n = 8: field boundaries where the beneficial insect sampling was performed, n = 7: without outlier.

X	Y	a	b	r	n	P
FMCII	%Weediness	-0.16	62.46	-0.30	62	0.019*
FMCII	Plant species richness	0.17	23.93	0.35	62	0.005**
Plant species richness	% Weediness	-0.53	72.15	-0.47	62	0.0001***
FMCII	% Weediness	-0.36	73.57	-0.75	8	0.033*
FMCII	Plant species richness	0.27	21.05	0.65	8	0.081
FMCII	Insect density	-0.14	16.06	-0.66	8	0.076
% Weediness	Insect density	0.33	-8.83	0.75	8	0.033*
% Weediness	Insect density	0.44	-14.47	0.93	7	0.002**
Plant species richness	% Weediness	-0.88	87.13	-0.76	8	0.030*

Principal Components Analysis

Principal Components Analysis of the 49 plant families with weediness, FMC integrity and the beneficial insect families as passive 'environmental' variables (Fig. 1) shows that plant families containing mostly woody species were characteristic of FMCs with a high integrity value and a high plant species richness. FMCs with a high percent weediness were characterised by species belonging to the Brassicaceae and the Polygonaceae families. Coccinellidae were most abundant in FMCs containing a high number of Chenopodiaceae and Malvaceae, whereas the Chrysopidae were most abundant in FMCs characterised by plant species of the Apiaceae. No Syrhidae were recorded.

These data show that the beneficial insects present in the FMCs are related to weedy species belonging to various families. This indicates that functional biodiversity in agroecosystems does not necessarily increase with increasing species richness, but is more related to the presence of certain keystone (Clergue et al., 2005) species, in this case weed species. Therefore, to maintain a high plant species diversity without compromising the on-fam functional diversity, it is necessary to maintain a high diversity in FMCs, structurally as well as management wise and there is no such thing as an ideal FMC structure.

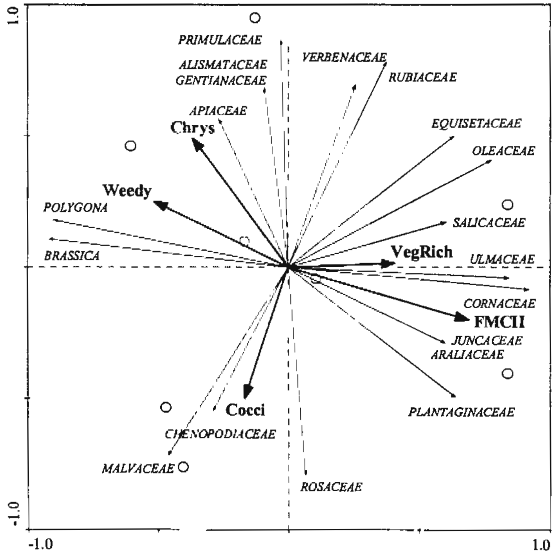

Figure 1. Principal Components Analysis of the 49 plant families, showing only the 19 most important ones, and the Field Margin Complex Integrity Index (FMCII), weediness (Weedy), plant species richness (VegRich) and Coccinellidae (Cocci) and Chrysopidae (Chrys) densities.

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The importance of alpine pasturing for the conservation of biodiversity - Intermediate results of the Interreg IIIB – project AlpNaTour

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Abstract: Mountain agriculture and alpine pasturing formed over centuries cultural landscapes with high biodiversity. In the Italian alpine bow the development of permanent grassland is characterised by a dramatic decrease. To preserve those ecologically valuable cultural landscapes, certain areas were declared as Natura 2000 sites. The implementation of the Natura 2000 network in general and the conservation of such man-made rural habitats often need specific management plans. In the framework of the EU-project AlpNaTour a management plan for a Natura 2000 site, located in a still agriculturally used area of the Stelvio National Park/South Tyrol (Italy) was developed. The complex interrelations between the requirements for maintaining alpine pastures and the protection of flora and fauna became obvious through a questionnaire-based analysis. Starting from this specific case the paper points out the challenges encountered in the elaboration of the management plan. Finally it gives indications whether the support of the analysed alpine pastures is reasonable or not.

Key words: Natura 2000, biodiversity conservation, management plan, alpine pastures

Introduction

The European network of protected areas Natura 2000 constituted by the Birds Directive[1] and Habitats Directive[2] contributes to ensure biodiversity including ecologically valuable natural and semi-natural habitats. At present this European initiative enters in its implementation phase. In Natura 2000 sites the maintenance or the development of the favourable conservation status of the habitats is implemented by measures on a landscape scale. These consider not only the environmental requirements of the site, but also the social and economic conditions of the region (Habitats Directive, Art.2).

The Habitats Directive (Art. 6) recommends the solution of conflicts emerging from all these requirements through management plans. At the same time it leaves a wide scope to the Member States for their elaboration. Therefore States and even regions applied different approaches.

The idea to compare and harmonise all these different approaches including guidelines and methods was the starting point for a European research project. The Interreg IIIB-project AlpNaTour aims at developing a guideline and checklists for the elaboration of management plans in the alpine space. Best practice will be derived from the analysis of existing guidelines and the application of different promising methods and approaches in Natura 2000 sites located in the alpine bio-geographic region.

The Italian sites investigated within the project are located in the Stelvio National Park in South Tyrol. The Stelvio National Park (1346 km^2) is one of the largest in the alpine bow and

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[1] Council Directive 79/409/EEC of 2 April 1979 on the Conservation of Wild Birds (Birds Directive). OJ L 103, 25.4.1979, p. 1.

[2] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (Habitats Directive). OJ L 206, 22.7.1992, p. 7.

connects to the Swiss National Park and to the Italian Natural Parks Adamello-Brenta and Monte-Tessa. One of the main targets in this vast network of habitats is to create the best conditions for the conservation and development of biodiversity. Here specific instruments contribute - especially within open cultural landscapes - to regulate the interests of both biodiversity conservation and agricultural land use. One of these instruments is the management plan and it will be developed for the Italian Natura 2000 site "Chavalatschalm" (IT 3110040). This area measures 3521 ha and its elevation ranges from 1358 m to 2935 m. The present habitats can be described as alpine and boreal heaths, siliceous grasslands, semi-natural dry grasslands with important orchid sites and mainly acidophilous *Picea* forests of the montane to alpine levels.

Mountain agriculture with alpine pastures is the main land use on site and responsible for the important rural habitats with high biodiversity (Dietl, 1995). Their favourable conservation status only subsists as long as the use of alpine pastures continues. Grazing these highlands may even increase biodiversity (Sarmiento, 2006). But the management of alpine pastures is not profitable anymore and needs financial aid. Since landscapes - like alpine pastures - are not valued in monetary terms, the challenge is to judge the appropriate provision and disposition of supporting landscape conservation (Hadjigeorgiou et al., 2005). So the main question is, whether the support of alpine pastures through expensive measures is also reasonable – despite of the Natura 2000 aim - considering the socio-economic requirements of regional development.

The profitability of the alpine pastures has been analysed in an empiric study. It revealed the actual situation of the alpine pastures and analyzed their carrying capacity. Based on the results of this study, trends about the future prospects of the alpine pastures and indications for the elaboration of the management plan are derived.

Method

The three alpine pastures located within the site were examined during summer 2005. Here dairy cows are held over the summertime and their milk is directly processed into cheese and butter. Each alpine pasture belongs to a municipality and is organised by the elected foreman. All farmers of the respective municipality have the right to drive their dairy cows up on the alpine pasture.

The study was divided into two steps. First the alpine pastures themselves were surveyed in terms of infrastructures, type of management, working conditions and livestock. Important information was gathered from interviews with the foremen of the three pastures.

In the second step, the individual situation of 38 farmers using the alpine pastures was analysed. If general agricultural conditions are poor, no successors are found for the farms and as a consequence also the alpine pastures will be abandoned. Therefore quantitative and qualitative information about the general circumstances of the farms was gathered through a structured questionnaire. An open-ended interview focussed on the intentions of the farmers about the future management of their farms in the valley and the use of the alpine pastures. Open-ended responses allow a qualitative interpretation of the analysis.

Results and discussion

Actual condition of the alpine pastures

The infrastructure and working conditions of two of the three analysed alpine pastures are on a high level. Their foremen think positive about the future and envisage several projects for ongoing improvement. The infrastructures of the third alpine pasture would need restoration works, but those won't be carried out as long as no street connects the alpine hut to the valley villages. Subject to these circumstances its foreman is not positive about the future. He fears that within the next years even less farmers will use his alpine pasture. Also the engagement and motivation of personnel like shepherds and workmen for milk products become harder and harder. For the continuity of management of this alpine pasture the construction of the connecting street is the essential factor. Finally the general decrease of dairy cows held on these three alpine pastures in the last decades has to be mentioned.

Future successors of the farms

The key factor for the future of every alpine pasture is the number of farmers using it. Their number as well as the number of dairy cows continually changes, depending on the general agricultural conditions. In addition not every farmer has a successor in prospect. Only 31,6% of the asked farmers know who will be taking over. From the remaining 68,4%, those farms are at risk to get abandoned within the next 10-15 years, whose farmers are over 60 years old. This applies to 21,1% of the asked farmers (Fig. 1). In consequence one fifth will not use the alpine pasture anymore. Interesting in this case is that 81,8% of the asked farmers think, that the conservation of cultural and rural landscape is "very important" or "important".

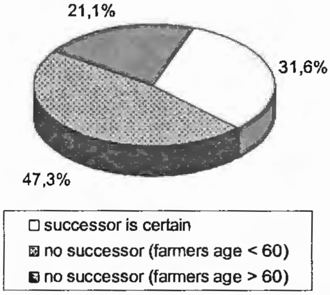

Figure 1. Amount of farms with prospect of a successor (considering the farmers age).

Conclusion

In the face of these results the management of the alpine pastures will go under the limit of profitability. A support is therefore economically not reasonable. Consequently the current land use with alpine pastures as a form of landscape management is not guaranteed for the future. Land use change results in site-related successional processes of the vegetation type. Vegetation of alpine pastures develops after the abandonment to forest as the secondary climax vegetation, loosing the high biodiversity of the alpine pastures (Tasser et al., 1999). Acting in the sense of Natura 2000 would mean to adopt measures against the loss of biodiversity and consequently to support the alpine pasture. Even if supporting the alpine pastures is not reasonable from an economic point of view it is from the environmental one.

But in some cases, like in the third analysed alpine pasture, only drastic and expensive measures like the construction of a connecting street would be an effective support. Indeed the street would facilitate the management of the alpine pasture. The accessibility of the alpine pasture by car would motivate more personnel to work there and allow interventions by the veterinary. Also the forage and the cattle itself could be easily transported by tractor. Furthermore the needed restorations on the infrastructures of the alpine pasture would be reasonable and improve the working conditions. But this intervention would surely endanger the habitat itself and his rare species. The street would cut through a courtship-place of *Tetrao urogallus* (protected through the Birds Directive). The wood grouse is adapted to this type of cultural landscape with alpine pastures, needing their man-made open spaces for the courtship and as feeding places (Möckel, 2002). The dissection of habitat represents the biggest danger for the protection of *Tetrao urogallus* in the alpine space (Suchant, 2002). This intervention would not help to achieve the aims of Natura 2000 in the sense of protection of endangered species. Accordingly the construction of the street cannot be proposed in this Natura 2000 management plan, even if it would support the management of the alpine pastures. Different alternative projects to the construction of the street as a funicular for example have to be taken under examination.

The management plan has to deal with an old vicious circle of the actual reality of cultural landscape in the alpine space. Only the use of the alpine pasture contributes to the conservation of semi-natural habitats, but this form of traditional land use is not profitable anymore. The economic incentives given by the Province support the alpine pastures but it is not sure that they will also be enough for assuring their maintenance. As Giupponi et al. (2006) showed in their study, on-site dairy processing gives the opportunity of development of agri-tourism with high-quality products. So, all possibilities to conserve these alpine pastures have to be discussed. Based on this study and in consideration of the socio-economic aspects of the region and the conservation aim of the Natura 2000 habitats specific measures will be derived and tailored conflict-solutions will be developed. So the management plan can be an instrument to interrupt this vicious circle.

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Overwintering ecology of *Coccinella septempunctata*, *Beauveria bassiana* and *Dinocampus coccinellae*

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Abstract: Under the adverse conditions of winter, adult ladybirds in temperate regions persist in a dormant state. Mortality during winter can be high and is largely attributed to *Beauveria bassiana* (fungal pathogen) and *Dinocampus coccinellae* (braconid parasitoid). We studied populations of *Coccinella septempunctata* in semi-natural field arenas throughout the winter (November 2004 to March 2005) to assess the temporal occurrence of mortality agents. We can confirm that the two main mortality agents of *C. septempunctata* during this winter period were *B. bassiana* and *D. coccinellae*. In mid winter (January) *D. coccinellae* was the major mortality agent and in late winter (March) *B. bassiana* dominated. Mortality of *C. septempunctata* due to infection by *B. bassiana* was always higher in individuals overwintering on their own compared to those that were part of an aggregation. Conversely, mortality of *C. septempunctata* due to *D. coccinellae* was always greater in individuals that aggregated compared to those found singly. These results are discussed with respect to physiological and ecological factors.

Keywords: *Coccinella septempunctata, Dinocampus coccinellae, Beauveria bassiana,* overwintering ecology, mortality

Introduction

The importance of aphidophagous ladybirds as a component of functional biodiversity is widely recognized (Dixon, 2000). Adult ladybirds in temperate regions spend the adverse conditions of winter in a dormant state (overwintering). For some species, such as *Coccinella septempunctata* (Coleoptera: Coccinellidae), this period of diapause is essential for reproductive maturation (Majerus, 1994). However, ladybirds experience high mortality during winter and this is attributed to both abiotic and biotic factors. Fungal pathogens and parasitoids (predominantly *Beauveria bassiana* (Hypocreales: Clavicipitaceae) and *Dinocampus coccinellae* (Hymenoptera: Braconidae) respectively) are known to be the main biotic mortality agents of *C. septempunctata* but very little is known about fundamental aspects of their interactions with overwintering ladybirds (Hodek & Honek, 1996; Riedel & Steenberg, 1998). In this paper we present results of a field study designed to assess the behaviour of *C. septempunctata* adults during winter and in particular the impact of *B. bassiana* and *D. coccinellae* on a temporal and spatial scale.

Materials and methods

Twelve 14.5 litre buckets were used to create semi-natural overwintering arenas for field collected ladybirds (Fig. 1). Each bucket was filled with a depth of 6 cm soil (collected from deciduous woodland) and then a PVC mesh bag placed inside to line each bucket. The mesh bag was filled to a depth of 10 cm with soil (6 cm) and deciduous woodland leaf litter (4 cm).

Field collected *C. septempunctata* adults were placed into the mesh bags (20 males and 20 females per bag) which were sealed at the top with an elastic band to prevent the ladybirds from escaping. Holes in the base of the buckets and around the sides ensured adequate water drainage.

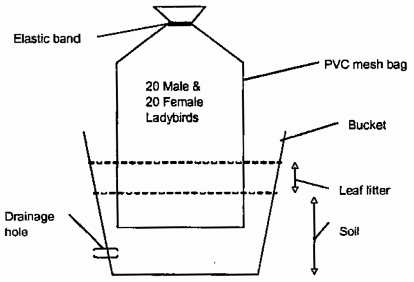


Figure 1. Cross section of semi-natural arena (14.5 litre bucket) used for overwintering experiments in the field.

The buckets were placed in the field, on level ground, under a small plantation of deciduous trees on the 15th of October 2004. Four buckets were randomly selected and destructively sampled at each of three collection points through the winter: early winter (15th November 2004), late winter (15th January 2005), early spring (15th March 2005). The last sampling time coincided with the normal emergence time of overwintering ladybirds. The aggregation status (single or aggregated) and weight (g) of each *C. septempunctata* was recorded. Each ladybird was then placed separately into 9 cm triple-vented Petri dishes and incubated at 22°C for two weeks. Mortality and cause of death was recorded daily (*B. bassiana*, *D. coccinellae* or unknown cause) and each ladybird was fed an excess of aphids. Dead *C. septempunctata* which initially showed either no sign of fungal infection or a parasitoid cocoon were placed in individual Petri dishes on moistened filter paper at 22°C and observed for fungal growth.

Results and discussion

The two main mortality agents of *C. septempunctata* during this winter period were *B. bassiana* and *D. coccinellae* (Fig. 2). In mid winter (January) *D. coccinellae* was the major mortality agent and in late winter (March) *B. bassiana* dominated.

Throughout the winter there were approximately equal numbers of males and female aggregated (Table 1) and mortality of *C. septempunctata* during winter was correlated with aggregation status (Fig. 3a and b).

Table 1. Mean percentage of male and female *C. septempunctata* found aggregated and singly at each of the three collection dates. Total percentage of aggregated and single *C. septempunctata* is also shown.

	November		January		March	
	Aggregated	Single	Aggregated	Single	Aggregated	Single
♂	30.8	19.4	39.5	8.1	32.1	15.0
♀	34.4	15.4	30.8	21.6	29.4	23.5
Total	65.2	34.8	70.3	29.7	61.5	38.5

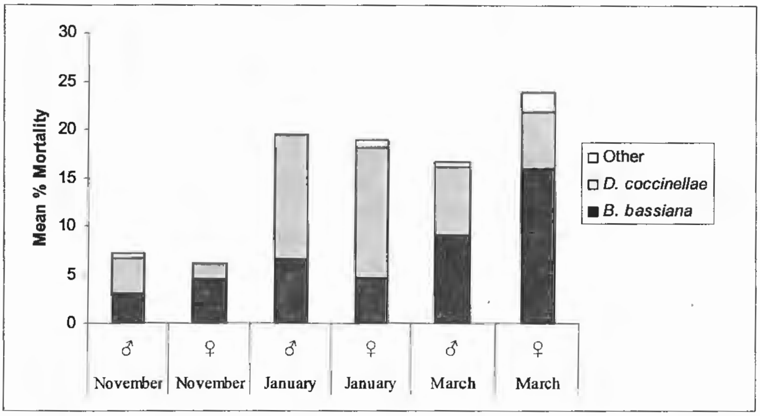
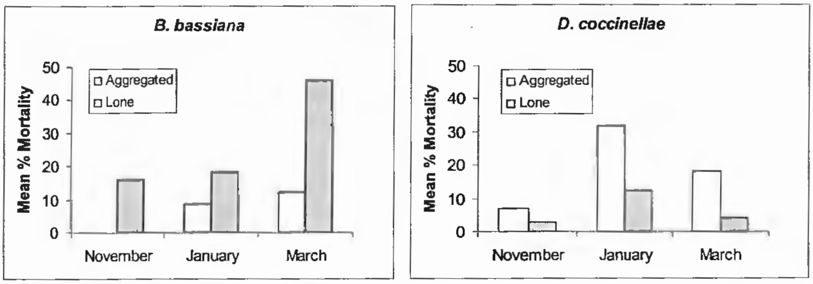


Figure 2. Mean percentage mortality of male and female *C. septempunctata* (attributed to *D. coccinellae*, *B. bassiana* or other causes) during winter (November 2004, January 2005 and March 2005).

Mortality of *C. septempunctata* due to infection by *B. bassiana* was always greater in individuals overwintering singly and significantly so in November ($\chi^2 = 10.584$, df = 1, $p < 0.005$; Fig. 3a) and March ($\chi^2 = 26.660$, df = 1, $P < 0.001$; Fig. 3a). This may be as a consequence of avoidance behaviour; uninfected ladybirds moving away from infected individuals. Meyling & Pell (2006) demonstrated the repellent effect of *B. bassiana* conidia to the generalist predator *A. nemorum* when the fungus was presented on nettle leaves or sporulating from an aphid host.

Conversely, mortality of *C. septempunctata* due to *D. coccinellae* was always greater in individuals that aggregated compared to individuals found on their own and significantly so in January ($\chi^2 = 7.610$, df = 1, $P < 0.05$; Fig. 3b) and March ($\chi^2 = 7.862$, df = 1, $P < 0.05$; Fig. 3b). Optimal foraging theory would predict that after a parasitoid has located an aggregation of suitable hosts it will oviposit in a high proportion of the individuals (Thiel & Hoffmeister, 2004).



Figures 3a and b. Mean percentage mortality attributed to *B. bassiana* or *D. coccinellae* of *C. septempunctata* overwintering either in aggregations or singly through the winter (November 2004, January 2005 and March 2005).

Previous population studies on *D. coccinellae* have only quantified mortality at the end of winter and so there is little information available to explain the high percentage mortality due to parasitism by *D. coccinellae* in January. One possible explanation is that greater mortality of developing parasitoid larvae may occur in late winter compared to mid winter because the ladybirds' energy reserves are depleted at this time and may be insufficient for parasitoid development. Although a greatly enlarged fat body is a conspicuous feature of diapausing coccinellids (Sluss, 1968; Hodek & Honek, 1996; Mills, 1981), our studies indicated a decline in ladybird weight through winter.

In conclusion this study indicates that *B. bassiana* and *D. coccinellae* are important mortality agents of *C. septempunctata* during winter and that the interactions between these natural enemies and ladybirds are complex.

Acknowledgements

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The role of cultivars on the structure of oilseed rape entomofauna

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Abstract: Rape is a food plant for a large number of insects. Since few cultivars of rape are grown in Bulgaria, the purpose of our research was to study the role of the cultivar as host plant for the rape entomofauna. The study was carried out during the period of 2004-2005 on the experimental field of the Department of Entomology, Agricultural University, Plovdiv. Four oilseed rape cultivars have been studied. Standard entomological methods were used to determine the population density of the entomofauna. Based on that data it was concluded that the different cultivars of oilseed rape crop differ in their host plant abilities for species belonging to the following orders: Homoptera, Hemiptera, Coleoptera.

Key words: oil seed rape pests, beneficial entomofauna, cultivars,

Introduction

Over the past few years, the importance of oilseed rape increased and the areas cultivated with this crop continuously raise. Regardless of its valuable biological, economical and agrotechnical qualities and advantages the crop creates a lot of plant protection problems, particularly if the specific climate and soil conditions in Bulgaria are considered.

In first studies on rape pests in Bulgaria the important role of the blossom beetle (*Meligethes aeneus F*)., and the damage activities of members of the genus *Phyllotreta*, the cabbage stem flea beetle (*Psylliodes chrysocephala*), the rape stem weevil (*Ceutorhynchus napi*), the cabbage seed weevil (*C. Assimilis*), the turnip (beet) sawfly (*Athalia colibri Christ.*) and the brassica pod midge (*Dasyneura brassicae Winn*) were described by Bogdanov & Nikolova (1945), Dirimanov & Angelova (1964), Angelova (1967), Arabadjiev (1959) and Kircheva (1991) among others.

In his studies Osipov (1995) described about 30 oilseed rape pests under the agro-ecological conditions of the Ukraine. Eighteen of them belong to the order Coleoptera and they are economically important during all phases of the oil seed rape development. Osipov (1995) above all mentioned *Psylliodes chrysocephala,* and *C. napi* as important pests. In some other regions of the world, the pest species composition of oilseed rape is often different (Johnen 2000, Amalnulah Khan et al., 1995).

It can be hypothesized that apart from different climatic conditions the different cultivars grown contribute to the locally different pest status of rape pests. Hence the diversity of the cultivated oilseed rape cultivars in Bulgaria, as well as the contemporary integrated pest control systems of this crop may influence composition of the pest complex. Consequently the purpose of the present investigation was to study the influence of the mentioned factors on the structure of the rape entomofauna.

Material and methods

The study was conducted during the period of 2004-2005 on the experimental fields of the

Department of Entomology at the Agricultural University, Plovdiv. The trial was set up applying the Rumker's method for analyzing consecutive and orderly arranged treatments and replications (without random arrangement of treatments and replications). The following cultivars were tested: Rasmus (I cultivar), Wotan (II cultivar), Panther (III cultivar) and Express (IV cultivar).

The density of the pest and beneficial species was determined using standard entomological methods such as sweep net sampling, yellow pans, etc. The insect collections with sweep nets were carried out in a 5-7 day interval. The samples were taken when the weather was warm, calm and sunny, and the insects settling on the top parts of the plants. Each sample included hundred swings. The caught insects were identified to orders, families and species.

The yellow pans were used to catch flying insects, which were attracted to yellow color. Yellow dishes filled with 4%-formalin were exposed by the use of wooden sticks fixed into the ground at equal height as the top of the rape plants. The pan traps were checked once a week. The data were processed by the method of Fisher.

Results and discussion

Pest species

It was found that the order Orthoptera represented only a small number of the total amount of pest insects in rape. The cultivars studied were good host plants for aphids (order Homoptera). Maximum population density of aphids was observed in the cultivar Express. Most likely, the higher density of aphids found in that cultivar may be caused by the higher content of oil which was found for other cultivars, too by Manthey (2004).

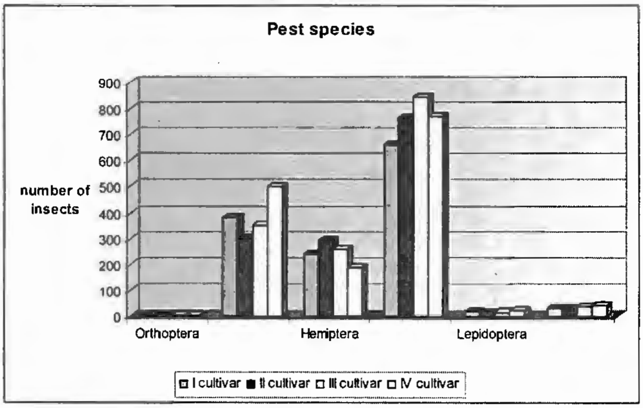

Figure 1. Insect numbers from different orders found in the different cultivars.

Furthermore, biometrical data show that the cultivar Express differs from other varieties by faster growth, which may offer better nutritional conditions for the development of pest insects. It is possible that biometrical data are the main reason for the variability in pest population densities on the different cultivars.

Regarding the population density of the species of the order *Hemiptera*, differences have also been found. The highest number was accounted in the cultivar Wotan. The height of this cultivar is almost the same as Express, but the number of leaves attached to the side branches is lower.

Representatives of the order Coleoptera were the largest fraction of the pest entomofauna and represented the highest species diversity. They were found in maximum densities on the cultivar Panther. Regarding the plant growth characteristics, this cultivar considerably differs from the others – it is the tallest with the largest number of leaves. Another interesting indicator is the color of the flowers with a slight touch of orange, which could be responsible for especially attracting that insect species which attack the crop during the blooming period.

Members of the order Lepidoptera were not among those species preferring oilseed rape as a host plant and can be classified as secondary important pests. Moreover the turnip (beet) sawfly (*Atalia colibri Crist.*) as a representative of the *Hymenoptera* order was observed in all cultivars but in a low density.

Beneficial species

The population density and the species composition of the beneficial insects was highly correlated with their food specialization.

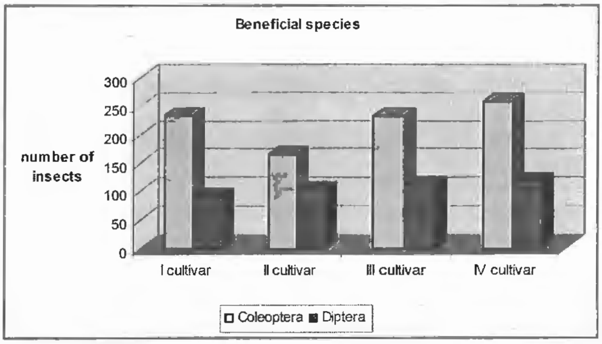

Figure 2. Proportion of beneficial insects from the orders Coleoptera and Diptera found in the different cultivars.

The seven-spotted lady beetle *Coccinella septempunctata* L., the two spotted ladybird *Adalia bipuctata* L. and the hoverfly *Scaeva pyrastri* L. were often found. They mainly preyed upon aphids settling on the oilseed rape plants. Highest densities were found on the cultivar Express.

Indifferent Species

The indifferent species were mainly represented by the Apidae, with very high numbers in the cultivar Panther which is most likely related to its specific coloring.

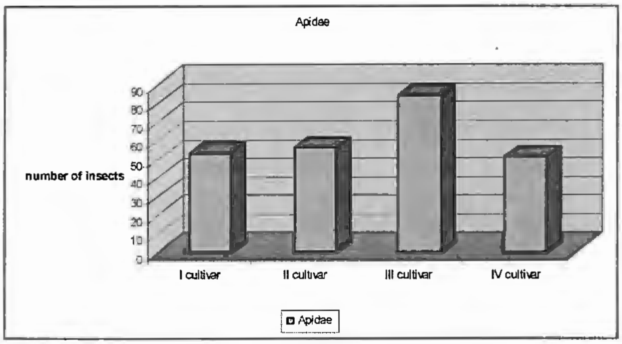

Figure 3. Proportion of the indifferent species in the different cultivars.

Conclusions

- The diversity of insect species and the density of individuals from different species is dependent on the specific morphological and physiological-biochemical characteristics of oilseed rape cultivars.
- The population densities and the species composition of the predators are closely related to the prey abundance.

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Establishment of a polyphagous mirid predator in the crop: The importance of non-cultivated plants

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Abstract: Insect predators of the genus *Macrolophus* (Hemiptera: Miridae) are important natural enemies of aphids and whiteflies in vegetable crops in the Mediterranean basin. Their maintenance in the agroecosystems is related with the conservation of their non-cultivated host plants. The importance of the non-cultivated plants *Solanum nigrum* and *Dittrichia viscosa* for the conservation and the establishment of *Macrolophus* in a tomato field was investigated. Samplings were conducted from a tomato crop and neighbouring *S. nigrum* and *D. viscosa* plants at weekly intervals from 4 May until 14 September 2005. *D. viscosa* was found to host relatively high numbers of *M. caliginosus* for the entire sampling period whereas, *S. nigrum* was proved to host relatively low numbers of *M. pygmaeus*. The numbers of *Macrolophus* were found higher at the outer rows of the crop close to the *D. viscosa* plants. This result indicates that the maintenance of non-cultivated host plants of *Macrolophus* species on field edges could contribute in the colonization of nearby fields. The results from molecular analysis of the *Macrolophus* samples from tomato showed that they were genetically identical to those on *S. nigrum* plants. Further research is needed to evaluate the dispersal rate and other factors that may be involved in the colonization rate of tomato crops by *Macrolophus* predators in the open field.

Key words: *Macrolophus pygmaeus*, *Macrolophus caliginosus*, biological control, tomato, aphids, weed

Introduction

The maintenance and the population fluctuations of insect natural enemies in agricultural habitats are closely related with the presence of their non-cultivated host plants. In agroecosystems in which non-cultivated host plants are conserved the colonization of our crops with natural enemies can be enhanced (Gurr et al., 1998; Altieri and Nicholls 2004).

In Mediterranean vegetable agroecosystems the insect predators *Macrolophus pygmaeus* (Rambur) and *Macrolophus caliginosus* Wagner (=*M. melanotoma*) (Hemiptera: Miridae) are very common (Alomar et al., 1994; Lykouressis et al., 2000). These species are effective biological control agents of whiteflies and aphids on tomato crops (Gabarra and Besri, 1999).

The non-cultivated plants *Solanum nigrum* and *Dittrichia viscosa* are the main host plants for *M. pygmaeus* and *M. caliginosus*, respectively (Alomar et al., 1994; Lykouressis et al., 1999-2000). Both plants species are very common in the vegetable agroecosystems. The potential of natural vegetation to contribute to the colonization of crops with mirid predators has been examined with encouraging results (Alomar et al., 2002; Sanchez et al., 2003; Castañé et al., 2004).

The aim of the current study was to investigate the seasonal abundance of the *Macrolophus* predators on the non-cultivated host plants and the importance of these plants in the colonization of a tomato crop by *Macrolophus* predators.

Materials and methods

The establishment of *Macrolophus* predators in a tomato field was investigated in relation to the non-cultivated plants *Solanum nigrum* and *Dittrichia viscosa* that grew naturally in the field edges. This work was conducted in an elongated tomato field (120x30m), located in the region of Kyparissia in western Peloponnesus. The numbers of *Macrolophus* and its prey were recorded on leaf samples collected from the tomato and the *S. nigrum* plants, but on *D. viscosa* they were recorded by visual inspection of stems. The samples of tomato (each sample was a newly mature leaf) were collected from predetermined sampling sites: the experimental plot consisted of 13 rows of tomato plants parallel to its long side and 17 samples from each third row were taken. The distance between two successive sampling sites on a row was 3m. However, from the last row of tomato plants 15 samples were taken. Therefore, 100 samples were taken in total from 5 plant rows, on each sampling date. In addition, 75 leaf samples were collected from *S. nigrum* plants that grew naturally along one of the long field sides. Along the opposite long field side D. *viscosa* plants (shrubs) grew. Observations were made to record *Macrolophus* nymphs and adults and potential prey on 20 stems of *D. viscosa*. In all cases, samplings were conducted at weekly intervals starting from 4 May until 14 September 2005. No insecticides were applied.

M. pygmaeus is very difficult to distinguish from the morphologically closely resembling *M. caliginosus*, although crossing experiments and molecular methods proved that these are two different species. *M. caliginosus* was the only *Macrolophus* species recorded on *D. viscosa* in a related study conducted in w. Peloponnesus (Perdikis et al., 2003). For these reasons the identity of the *Macrolophus* individuals from tomato, *S. nigrum* and *D. viscosa* was established using molecular methods. This was done by collecting samples in May and July from all the host plants. To evaluate variability different collections were screened with two selected oligonucleotide primers (OPA 18 and OPA 20) in RAPD-PCRs. A total of 31 polymorphic markers were scored, the combination of which resulted in 16 distinct electrophoretic patterns. Genetic relationships were estimated by the unweighted pair-group method with arithmetic averaging (UPGMA).

Results

On *S. nigrum* the aphid *Aphis fabae solanella* Theobald was recorded from the beginning of the sampling until mid-June. Its numbers peaked in mid-May with 19.67 aphids per sample. *Macrolophus* were present on the *S. nigrum* plants in June and from middle of August until the end of the sampling period with highest number recorded on June 22 (0.27 individuals per sample).

On *D. viscosa* the aphid *Capitophorus inulae* (Passerini) was recorded in May with highest numbers in mid-May when its population was 4 individuals per stem. On *D. viscosa*, *Macrolophus* were present throughout the sampling period with higher numbers in May, June and July, with highest densities in late May reaching 4.06 individuals per stem, and in early July reaching 4.61 individuals per stem.

On tomato plants the aphid *Macrosiphum euphorbiae* (Thomas) was recorded from the beginning of the sampling period until the end of June with highest numbers occurring in mid-May and mid-June reaching to 1.5 individuals per leaf sample. Other potential prey for the predators such as whiteflies was recorded in very low numbers. *Macrolophus* were recorded on tomato during the entire sampling period but with highest numbers from the end June to the end of July. Its numbers peaked on 29 June reaching 1.42 individuals per leaf.

The numbers of *Macrolophus* were significantly higher in the outer row of tomato plants at the field edge where the *D. viscosa* plants grew and decreased with the increase of the distance of each row from this edge (0.59, 0.542, 0.55, 0.41 and 0.31 individuals on average were recorded per sample in each row for the entire sampling period). However, the numbers of the aphid *M. euphorbiae* were higher in the middle rows (0.08, 0.17, 0.76, 0.80 and 0.28 individuals on average were recorded per sample in each row for the entire sampling period).

Molecular analysis of the *Macrolophus* collected from the different host plants showed that two main groups exist. The first group consists of the collection from *D. viscosa* plants and the second the collections from tomatoes and *S. nigrum* plants.

Discussion

The non-cultivated plant *D. viscosa* was found to host relatively high numbers of *M. caliginosus* for the entire sampling period. This finding agrees with those of previous studies showed the major role of this plant for the conservation and increase in numbers of *M. caliginosus* in the open field (Lykouressis et al., 2000; Perdikis et al., 2003). Therefore this plant is a main natural reservoir for this predator in the agroecosystem.

On the other hand, *S. nigrum* was proved to host relatively low numbers of *M. pygmaeus*. However, its importance in the maintenance of populations is considered to be of high value since this is the most important host plant for *M. pygmaeus*.

The numbers of *Macrolophus* were found higher at the outer rows of the crop close to the *D. viscosa* plants. This result indicates that the maintenance of non-cultivated host plants of *Macrolophus* species on field edges could contribute in the colonization of nearby fields. However, the results of the molecular analysis of the *Macrolophus* samples collected on tomato showed that they belonged to *M. pygmaeus* which however, was recorded on *S. nigrum* plants only. Therefore, before reaching to conclusions, further research is needed to evaluate the dispersal capacity of the predators *M. caliginosus* from *D. viscosa* and *M. pygmaeus* from *S. nigum* plants to tomato plants or possibly other factors such as dispersal from distant habitats.

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Wildflower strips to reduce lepidopteran pests in cabbage crops

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Abstract: Vegetable production systems are highly intensive and the periodic cultivations lead to unfavourable conditions for natural enemies. Using non-crops it is possible to create ecological infrastructure offering suitable food for natural enemies, and shelter from adverse conditions. On four organic farms in Western-Switzerland, we have tested in cabbage crops if wildflower strips are an appropriate tool to reduce lepidopteran pests. Analyses of wildflower strips on parasitism of caterpillars of *Pieris rapae* and *Mamestra brassicae* indicated a pest control potential. Grid trial using reared egg batches revealed no significant effect on parasitism of exposed *M. brassicae* and *Plutella xylostella* eggs in relation to the distance of the strip.

Key words: parasitoids, conservation biocontrol, vegetable, non-crop habitat, natural enemies

Introduction

Agroecosystems are unfavourable environments for natural enemies due to high levels of disturbance, habitat fragmentation and loss of suitable habitats (Gurr *et. al.*, 2004). Especially vegetable production systems are highly intensive and the periodic cultivations lead to unsuitable conditions for natural enemies. Therefore a diversification through habitat manipulation is essential to create an appropriate ecological infrastructure offering suitable food for adult natural enemies, alternative prey or hosts, and shelter from adverse conditions. Non-crop habitats lead to a general improvement of suitable refuges which serve as over-wintering sites and sheltering sites before and after crops have been harvested (Pfiffner & Luka, 2000). There are few field studies analysing flowering strips in vegetable crops (Lee & Heimpel, 2005; Winkler, 2005). The main question of this field study was to investigate if the use of the officially recommended wildflower strips is an appropriate tool to reduce key lepidopteran pests in organic cabbage crops.

Material and methods

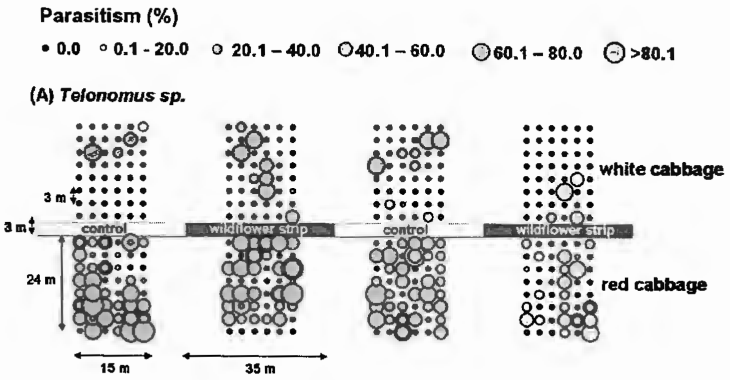
The parasitism of lepidopteran pest was investigated in relation to presence or absence of adjacent sown, species rich wildflower strips at four sites in arable landscapes of Western-Switzerland. A seed mixture was used containing 24 wildflowers which is officially recommended within the Swiss agri-environmental program to improve biodiversity on arable land (Pfiffner & Wyss, 2004). Naturally occurred caterpillars of *Pieris rapae, Plutella xylostella* and *Mamestra brassicae* have been sampled in unsprayed cabbage fields up to nine dates in 2001 and 2002. Three situations have been tested on two farms: (1) adjacent to the strip, (2) near to a strip (20 m up to 90 m) and (3) a control without any field margins. The strips were 3 m in width and 1- to 3-year old.

In a 2nd step on two farms, a grid trial was performed in order to analyse the spatial pattern of parasitism of *M. brassicae* and *P. xylostella* in relation to the distance of the one-year old wildflower strips. Batches of reared eggs were exposed during three days at four dates in 2004 and 2005. Egg batches were pinned to plants in a grid of 3 m to 3 m (up to 48 points per block) of the two fields on two farms. Each field consisted of two blocks, one with an adjacent wildflower strip and the other as a control plot without a wildflower strip (Fig. 1).

Results and discussion

Microplitis mediator, Cotesia rubecula and *Diadegma semiclausum* were found to be the most abundant parasitic wasps of caterpillars with an amount of 74%-94%. Egg parasitoids of diamond backmoth and cabbage moth were mostly *Telonomus sp.* and only in some cases *Trichogramma evanescens.*

The parasitism rate of *Mamestra brassicae* and *Pieris rapae* caterpillars was mostly higher in the cabbage fields adjacent to the wildflower strip than in the field without a strip. The parasitism rate of *P. rapae* decreased with increasing distance to the strip. In contrast, *Plutella xylostella* were found to be more parasitized in the treatments without strips.



(B) ***Trichogramma evanescens***

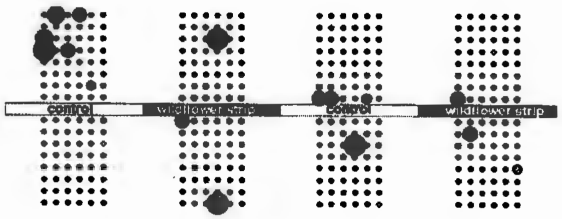


Figure 1. Exposed egg batches of *M. brassicae* parasitized by *Telonomus* sp. (A) and *Trichogramma evenescens* (B) in a grid of 3 m x 3 m. Pooled data of two dates 2004.

Using exposed egg batches of *M. brassicae* and *P. xylostella* within a grid trial revealed no significant effect in the distances of 3 m to 24 m from the wildflower strip. Eggs of *M. brassicae* were moderately (Fig. 1) and these of *P. xylostella* (1-2%) were rarely parasitized.

Our on-farm trials showed that wildflower strips may increase the parasitism of caterpillars of *M. brassicae and P. rapae*, but no reducing effects on *P. xylostella* - as egg as well as larval stage - were found. Furthermore, grid trial using reared egg batches revealed no significant effect on parasitism of exposed *M. brassicae* and *P. xylostella* eggs in distances of 3 m up to 24 m from the wildflower strip. Parasitism of *M. brassicae* eggs may also be greatly affected by landscape factors as Bianchi et al. (2005) found in Brussels sprout.

To increase pest-control a specifically tailored biodiversity to the needs of key natural enemies is necessary, and furthermore a general improvement of biodiversity on the whole farm may substantially enhance other natural enemies. It is a key issue to use selective plants in field margins with a minimal benefit for the pests. After a careful assessing of the suitability of flowering herbs, it is useful to develop crop-specific tailored wildflower strips (e.g. Wäckers, 2004; Winkler, 2005).

However, more knowledge on temporal-spatial dispersal pattern of natural enemies between non-crop and crop habitat on local and regional scale is needed to assess the efficiency for pest-control function.

Acknowledgements

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Functional biodiversity of aphid natural enemies: positive intra-guild interactions

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Abstract: When designing landscape management strategies to promote functional biodiversity for conservation biological control, it is important to understand how different natural enemies interact so that the most efficient guild can be enhanced. Aphid parasitoids detect the presence of ladybirds through chemical trails left by the predators on leaf surfaces, allowing the parasitoids to minimise intra-guild predation of their eggs and larvae. Polytunnel arena experiments also revealed that aphid parasitoids and the fungal entomopathogen *Pandora neoaphidis* can effectively co-exist despite the potential for competitive exclusion of the parasitoids by the fungus.

Key words: intra-guild interactions, aphid parasitoid, ladybird, fungal entomopathogen, semiochemical, predator avoidance, competitive exclusion

Introduction

Populations of aphid pests on agricultural field crops, such as cereals, can be prevented from reaching economic damage thresholds by the action of natural enemy guilds, including insect parasitoids and predators and fungal entomopathogens (Wratten & Powell, 1991). The management of non-crop habitats within agricultural landscapes, including sown grass/wild flower field margins, can conserve and enhance this functional biodiversity (Landis et al., 2000; Powell et al., 2003; Gurr et al., 2003). However, different approaches to the design and management of non-crop habitats will favour different components of the natural enemy guild and management could be tailored to benefit specific groups. For example, tussocky grass beetle banks benefit generalist predators such as carabid beetles (MacLeod et al., 2004), margins with abundant nectar-rich flowers benefit aphidophagous hoverflies (Cowgill, 1989; Krause & Poehling, 1995) and nettle (*Urtica dioica*) patches benefit aphid-pathogenic fungi (Perrin, 1975). Therefore, when designing landscape management strategies to promote functional biodiversity for conservation biological control, it is important to understand how different natural enemies interact so that the most efficient guild can be enhanced. Positive interactions between aphid parasitoids and ladybirds and between aphid-pathogenic fungi and both ladybirds and parasitoids have been elucidated in a series of recent studies at Rothamsted Research.

Ladybird avoidance by parasitoids

The eggs and larvae of aphid parasitoids develop within the living host and so are at risk from intra-guild predation by aphid predators. It would therefore be advantageous for adult female parasitoids to avoid laying their eggs in aphid colonies where predators such as ladybirds are present, but to achieve this they need to be able to detect the presence of such predators.

Although there was evidence that aphid parasitoids could avoid ladybirds (Taylor et al., 1998; Nakashima & Senoo, 2003), little was known about the mechanism involved. Nakashima et al. (2004) tested the hypothesis that foraging female parasitoids detected chemical trails left on plants by ladybirds and that the presence of these semiochemicals stimulated the avoidance behaviour. In dual-choice bioassays, females of the parasitoid *Aphidius ervi* foraged on broad bean (*Vicia faba*) leaves that had been visited by either adults or larvae of the seven-spot ladybird, *Coccinella septempunctata*, significantly less than they foraged on uncontaminated leaves (Fig. 1). The same result was obtained when leaves were treated with chemical extracts of ladybirds, obtained by cooling them with liquid nitrogen and then immersing adults (500) or fourth-instar larvae (150) in ethanol (400 and 50 ml, respectively) for 24 hours at 25°C (Nakashima et al., 2004).

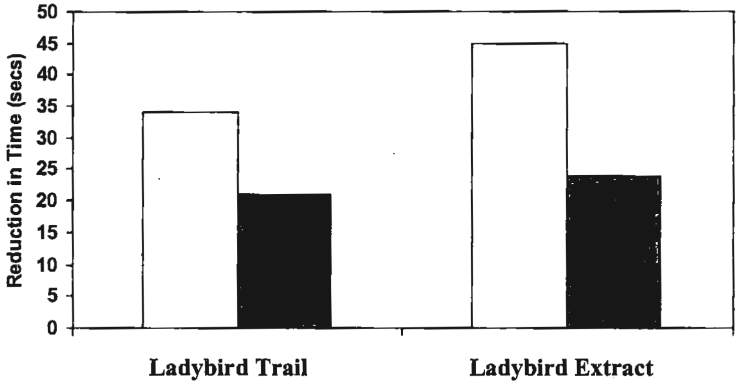

Figure 1. Reduction in time spent by female parasitoids on broad bean leaves contaminated with ladybird trails or treated with ethanol extracts of whole adult (blank columns) or larval (shaded columns) ladybirds, compared with untreated leaves, in dual-choice bioassays. ($p<0.05$ in all cases; n=20).

Chemical analysis of ladybird trails combined with further bioassays revealed that the active semiochemicals in the trails were the hydrocarbons *n*-tricosane ($C_{23}H_{48}$) and *n*-pentacosane ($C_{25}H_{52}$). Application of these chemicals to broad bean plants infested with pea aphids, *Acyrthosiphon pisum*, halved the numbers of aphids successfully parasitised when exposed to *A. ervi* females for 18 hours (Nakashima et al., 2004).

Parasitoid - pathogen interactions

Laboratory studies at a number of spatial scales have indicated that foraging predators and parasitoids enhance the transmission and dispersal of the entomopathogenic fungus *Pandora neoaphidis* within aphid populations (e.g. Roy & Pell, 2000; Ekesi et al., 2005) and that the combined effect of all three natural enemies can be additive with respect to aphid population regulation (Baverstock, 2004). However, the parasitoid *A. ervi* did not discriminate between living hosts infected with *P. neoaphidis* and those that were healthy (Baverstock et al., 2005) and, as a result of the shorter developmental period of the fungus, the parasitoid can be competitively excluded in hosts attacked by both fungus and parasitoid (Powell et al., 1986).

We hypothesised that on a larger spatial scale competition for hosts would be reduced and *A. ervi* would co-exist with *P. neoaphidis* unless environmental conditions were strongly biased in favour of the fungus. The reproductive success of parasitoids in aphid populations containing *P. neoaphidis* compared to those not containing the fungal pathogen was assessed in a polytunnel arena (Baverstock, 2004). A group of 40 female parasitoids was released six metres downwind from two patches of bean plants (nine plants per patch, each infested with 30 aphids). Thirty cadavers sporulating with *P. neoaphidis* were added to each of four plants within one patch only (treatment patch). Parasitoids were allowed to forage for 48 hours after which time all plants from both patches were covered with perforated bags and maintained at 18 degrees (16L:8D). The number of *P. neoaphidis* cadavers and *A. ervi* mummies was recorded after a further 16 days.

As expected, significantly more *P. neoaphidis*-sporulating cadavers were recovered from the treatment patch than the control patch ($p<0.05$); mean of 68.2 and 5.0 respectively (Figure 2). However, there were no significant differences in the number of parasitoid mummies recovered from the treatment and control patches ($p>0.05$); mean of 8.33 and 12.0 mummies respectively (Figure 2). Within the treatment patch, there were no significant differences in the number of mummies recovered from individual pots initially supplemented with fungal cadavers and those not containing the fungus ($p>0.05$).

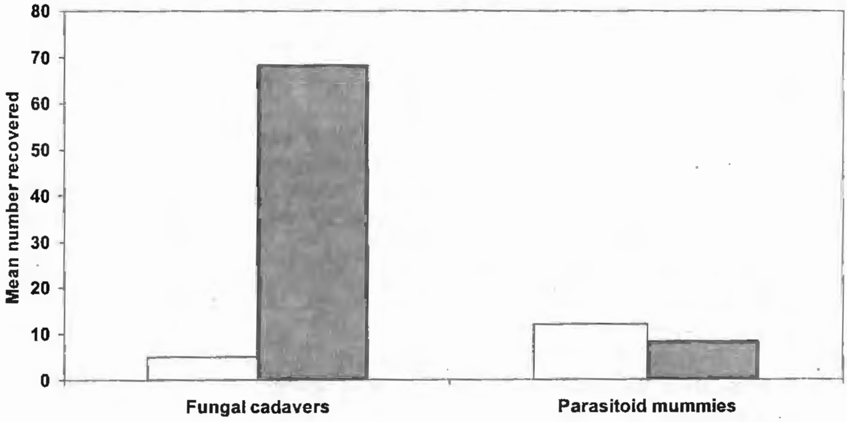

Figure 2. Mean number of *P. neoaphidis*-sporulating cadavers and *A. ervi* mummies recovered per plant from patches inoculated with *P. neoaphidis* (shaded columns) and from control patches (blank columns) after 16 days.

Although there is the potential for competitive exclusion of parasitoids by entomopathogens in this system, at larger spatial scales parasitoids do not appear to incur a fitness cost through foraging in patches containing *P. neoaphidis*, even in the presence of a large quantity of fungus and therefore fewer available hosts. There was a laminar air flow within the polytunnel arena and so it was surprising to find aphids infected with *P. neoaphidis* in the control plot, which suggests that parasitoids vectored infection between the plots.

Conclusion

Different landscape management techniques often benefit different components of the natural enemy guilds attacking pests such as aphids. Therefore, it is important to target management strategies to optimise functional biodiversity by encouraging combinations of natural enemies that minimise negative intra-guild interactions. Studies of interactions between different groups within aphid natural enemy guilds have revealed positive behavioural interactions that allow effective co-existence between parasitoids, ladybirds and fungal entomopathogens.

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Can geostatistics improve the understanding of spatio-temporal dynamics of soil arthropods within ecological infrastructures at farm-scale level?

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Abstract: Geostatistics have been used to study the spatial distribution of soil arthropods on ecological infrastructures and crops within a farm of northern Italy. In our study, spatial analysis by means of geostatistical tools showed in many cases a satisfactory visual image of the spatio-temporal dynamics of the ground arthropod fauna in relation to the habitats within the farm. Data confirms the importance of different types of ecological infrastructures for the conservation of beneficial soil arthropods at farm scale. A detailed knowledge of spatio-temporal patterns of arthropods seems to be crucial for a rational management of ecological infrastructures in order to improve beneficial arthropod conservation, including cyclic colonizers that play an important role in conservation biological control.

Key words: geostatistics, spatial patterns, ecological infrastructures, soil arthropods, ground beetles

Introduction

Ecological infrastructures are considered an important tool in multifunctional agriculture to utilize to the fullest extent the services of functional biodiversity and especially conservation biological control (Boller et al., 2004). The network of ecological infrastructures is essential for the development and efficiency of important beneficials, as they provide refuges, hibernation sites, alternate hosts, nectar, pollen, etc. (Landis et al., 2000). The spatio-temporal pattern of distribution of these elements concur to define the heterogeneity and complexity of the rural landscape. As most of the cases in landscape ecology, traditional statistical methods are unsatisfactory for insect data analysis, due to the lack of a suitable experimental design.

The aims of the research were: i) to evaluate the effectiveness of different ecological infrastructures for the conservation of terrestrial beneficial arthropods, and their influence on the insect distribution within the fields; ii) to define the spatio-temporal dynamics of soil arthropod fauna at the farm scale by the use of geostatistical methods; iii) to understand the dynamics of cyclic arthropod colonizers between crops and ecological infrastructures.

Material and methods

Experimental farm features

The sampling area was located at the University of Bologna experimental farm, situated in the "Parco dei Gessi Bolognesi e dei calanchi dell'Abadessa". The farm was conducted by IPM criteria. No chemical sprays were used for pest or disease control but only chemical fertilizers were used. An area of about 50 ha (Fig. 1) was sampled by means of 71 pitfall traps, filled with 50% ethylene glycol, and sampled monthly from May 2004 to December 2005.

Traps were arranged in an irregular grid, due to the heterogeneity of the experimental area. All the traps were geo-referenced by means of GPS system. Several microhabitats were selected and investigated: winter cereals, switchgrass, alfalfa, cherry wood plantation, woodland patches, set aside, field margins, and meadow plots and strips. Samples were sorted in the laboratory and the most abundant arthropod taxa were removed for subsequent identification.

Data analysis

Principal Component Analysis and Correspondence Analysis were performed to ordinate the different microareas within the farm in relation to the arthropod fauna. Geostatistical analyses were computed on arthropod data matrices using different approaches: Inverse Distance Weightning (IDW), variography and Ordinary Kriging. The software used for this purpose was ESRI® ArcView, Spatial Analist, and Surface Interpolator.

Results and discussion

General results (mean of sampling dates)

Carabids were identified to species level, while species identification of spiders and springtails is in progress. In general within-microhabitat variability of the arthropod abundances at the different sampling dates was very high.

Spiders showed a high within-farm and within-microhabitat uniformity; only the two main crops (wheat and switchgrass) showed a slight reduction in their activity-density. The highest activity-density patches of spiders were recorded in alfalfa fields, in the cherry wood orchard, in the set-aside, and in the switchgrass field and relative field margins. In most of these microhabitats spiders were also the most abundant predator group caught. Most of the ground beetles were recorded in managed and un-managed wheat field margins and in the set aside area adjacent to wheat. The catches of carabids outnumbered those of other predatory groups in some wheat field margins and in the woodland patch. Opiliones were mainly aggregated in wheat fields (main predator group). With regard to the decomposer guild, the most abundant springtail catches were mainly found in meadows, set aside and poorly managed field margins; their lowest activity-density was detected in woodland patches, intensively managed field margins, and all crop fields. With regard to woodlice, this group was mostly distributed in the switchgrass, set aside and meadow fields.

Results of geostatistical analysis

Geostatistical data analysis is in progress and preliminary results are shown. About 170 activity-density IDW and Kriging contour plots were drawn. IDW maps, in most of the cases, efficiently describe the spatial distribution patterns of the taxa within the farm. In general a strong difference in spatial patterns among taxa was detected. Moreover, spatial patterns of each group were characterised by consistent temporal variability. Different taxa of the same functional group, and different species of carabids, occupied different microhabitat areas, providing some evidence of «taxa packing in space» (Thomas et al., 2001) and/or intra-guild competition.

With regard to harvestmen, IDW showed strong aggregation patterns in winter wheat, both in the summers of 2004 and 2005. This pattern distribution is corroborated by the Correspondence Analysis. In wintertime of both seasons, the higher values of activity-density patches of this order were detected in the intensively managed winter wheat field margin; the reasons of this phenomenon are not clear. With respect to ground beetles, the winter wheat field margins showed the highest values of activity-density by means of IDW.

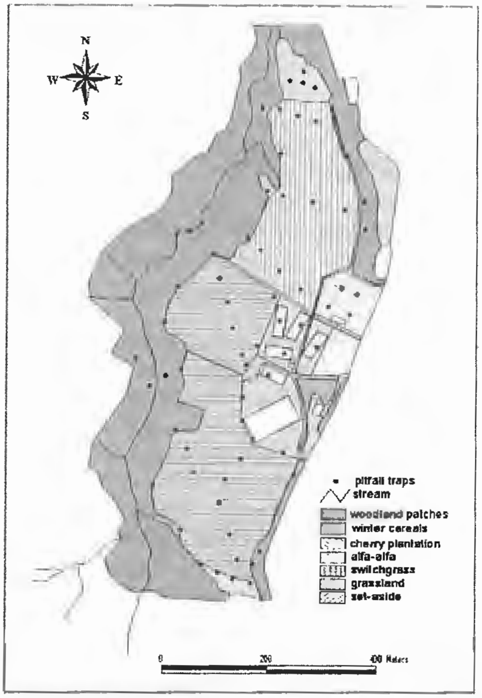

Figure 1. Experimental farm and within farm microhabitats (black dots indicate the location of pitfall traps).

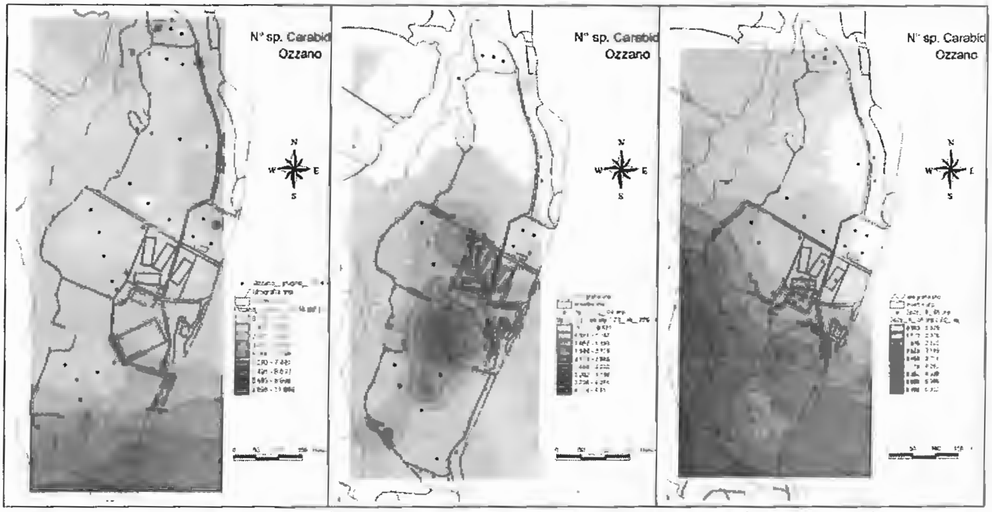

Figure 2. Spatial distribution (IDW contour plot) of the number of species of ground beetles caught in pitfall traps in June 2004, December 2004, and August 2005.

Also the distribution of the carabid species richness showed a strong spatial structure. The highest number of species of ground beetles was found in different winter wheat field margins: woodland patch boundary, set aside boundary, and intensively managed field margin (Fig. 2). The carabid activity-density and species distribution in the different types of ecological infrastructures showed a strong variability in relation to the different sampling dates, confirming the importance of different types of non-crop areas for the arthropod conservation and dynamics during the different periods of the year.

A detailed knowledge of spatial-temporal patterns of arthropods seems to be crucial for a rational management of ecological infrastructures and to design these elements within the farm. In our study, spatial analysis by means of IDW showed in many cases a satisfactory visual image of the spatio-temporal dynamics of the ground arthropod fauna in relation to the habitats within the farm.

The ecological importance of the predatory functional groups sampled in this study (spiders, ground beetles, rove beetles and harvestmen) and the decomposer functional groups (springtails and woodlice) is demonstrated in scientific literature (i.e. Holland et al., 2002; Paoletti, 1999). Our results confirm the importance of ecological infrastructures within the farm for the conservation of beneficial soil arthropods, including cyclic colonizers. The spatial pattern variability among taxa are probably related to the different ecological requirements and dispersion capacity of the investigated groups, that in some circumstances can be specifically highlighted by the gradients of physical, ecological and climatic factors within the farm.

Spatial analysis requires a detailed monitoring grid and great caution in the data analysis; each sampling program needs to be specifically designed in relation to the specific situation, adopting, for example, a stratifying sampling approach that seems particularly suitable for heterogeneous environments. The suitable spatial analysis approach must be selected very carefully, in order to avoid artefacts and incongruence in interpreting the data.

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Role of spontaneous plants as a reservoir of alternative hosts for *Semielacher petiolatus* (Girault) and *Citrostichus phyllocnistoides* (Narayanan) (Hymenoptera, Eulophidae) in citrus groves

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Abstract: The significance of spontaneous plants for the populations of two exotic parasitoids, *Semielacher petiolatus* (Girault) and *Citrostichus phyllocnistoides* (Narayanan), was investigated in five Sicilian citrus groves. Both species were obtained from two herbs typically growing beneath the citrus trees in the period of scarce availability of the target host, the citrus leafminer *Phyllocnistis citrella* Stainton. *S. petiolatus* was reared from *Cosmopterix pulcherimella* Chambers, a specific leafminer on *Parietaria diffusa* M. et K., while *C. phyllocnistoides* was reared from the same species and from a *Liriomyza* species associated to *Mercurialis annua* L. These last two host records are new and further broaden the known host range of these parasitoids, previously considered as specialists. Thus, natural vegetation diversity enhances the survival and maintenance of *S. petiolatus* and *C. phyllocnistoides* in citrus agroecosystems providing them with alternative hosts. Moreover, the incidence of parasitism of the two exotic parasitoids on non-target hosts was so low that a negative impact both on native leafminers and autochthonous parasitoid populations can be excluded.

Key words: natural vegetation diversity, host range, non-target effects, *Phyllocnistis citrella*

Introduction

Vegetation diversity in agroecosystems is considered the most important source of natural enemies (Altieri, 1991; Altieri et al., 2003; Rossing et al., 2003 and references therein; Gurr et al., 2004) and its function is believed to be more significant for generalist species than for specialists (Coll & Bottrell, 1996; Tscharntke et al., 2002). Therefore, we started to study the significance of spontaneous plants for the populations of *Semielacher petiolatus* (Girault) and *Citrostichus phyllocnistoides* (Narayanan), two exotic Eulophid parasitoids of the citrus leafminer *Phyllocnistis citrella* Stainton. Both species were largely used in inoculative releases against *P. citrella* in many Mediterranean countries and are considered the most effective biological control agents of this pest (Schauff et al., 1998; Garcia-Mari, 2003 and references therein; Garcia-Mari et al., 2004). The aim of this study was mainly to investigate whether natural vegetation diversity could enhance the survival and maintenance of the populations of these two exotic parasitoids in citrus agroecosystems, especially when the target host species in the crop is scarce.

Materials and methods

Samplings were carried out from July 2002 to July 2003 every 15 days in five Sicilian citrus groves: Parco d'Orleans, S. Flavia and Zucco in the province of Palermo, and Ribera and Menfi in the province of Agrigento: at each site 50 shoots of citrus plants were gathered to study the parasitization trend on *P. citrella*. At the same time samples of spontaneous plants with mines were collected in and around the citrus groves. For every site the infestation level of the citrus leafminer was evaluated by counting the number of larvae on 20 young leaves being 3-5 cm long (Caleca et al., 1996; Caleca et al., 1998). Leaves with mines both of citrus and spontaneous plants were placed separately into Petri dishes on wet paper and stored in an air-conditioned room (25°C, 70% r.h. and L14:D10) till the emergence of the leafminers and relating parasitoids. Each specimen was then mounted, labelled and identified. Parasitization has been calculated as the ratio between the emerged parasitoids and the total emerged insects.

Results and discussion

In many Mediterranean countries exotic parasitoids displaced native species in the control of *P. citrella* on citrus plants (Garcia-Mari, 2003 and references therein; Garcia-Mari et al., 2004), while in Sicily the contribution of autochthonous species has always been rather low (9-10% average parasitization: Caleca et al., 1996; Caleca et al., 1998). In this study *C. phyllocnistoides* and *S. petiolatus* fully prevailed over native parasitoids (96 vs. 4%) during the whole summer 2002, the latter being mainly represented by *Cirrospilus pictus* (Nees) (Hymenoptera, Eulophidae) (3.4%). Neither *C. phyllocnistoides* nor *S. petiolatus* were obtained from any of the alternative hosts reared from 19 native plant species collected during summer 2002, even if they hosted a large community of parasitoids, mostly belonging to Eulophidae (83.6%).

In four out of five citrus groves the two exotic species alternated with each other: *S. petiolatus* dominated in the first half of the season (max.: 55.1% in mid July), while *C. phyllocnistoides* prevailed from the end of July onwards (max.: 72.1% in mid September) (Fig. 1, on the left). Only in one citrus grove *S. petiolatus* was very rare (max.: 1.1%), but, despite of this, *C. phyllocnistoides* showed the same parasitization pattern as in the four other citrus groves: very low in the beginning of the infestation (5.3%) and gradually increasing from August onwards (max.: 81.3% in mid September) (Fig. 1, on the right).

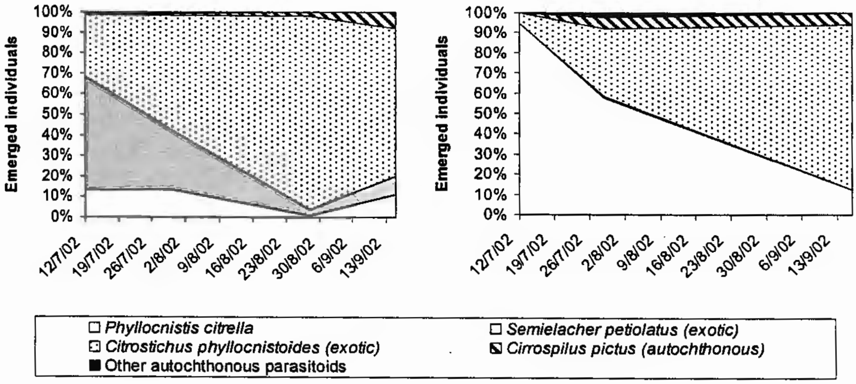

Figure 1. Parasitization trend on *P. citrella* in four Sicilian citrus groves where both exotic species were abundant (on the left) and in one citrus grove where *S. petiolatus* was rare (on the right) in summer 2002.

P. citrella infestation reached the maximum in July 2002 (5.1 larvae/leaf), decreasing from this point on and touching its minimum (0 larvae/leaf) from March 2003 onwards (Fig. 2). During the same period 19 spontaneous plant species, partially overlapping those found in the previous season, were collected. In June 2003 *S. petiolatus* was reared from *Cosmopterix pulcherimella* Chambers, leafminer on *Parietaria diffusa* M. et K., while *C. phyllocnistoides* was reared from the same species and from a *Liriomyza* species associated to *Mercurialis annua* L., these last two host records being new. Thus, *C. phyllocnistoides* and *S. petiolatus* found refuge on spontaneous vegetation in the period of scarce availability of *P. citrella* larvae on citrus plants (Fig. 2).

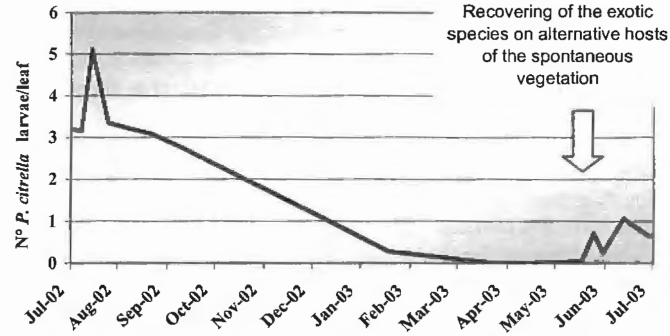

Figure 2. *P. citrella* infestation trend from summer 2002 to summer 2003 in five Sicilian citrus groves.

Our findings further broaden the known host range of the two exotic species (Massa & Rizzo, 2000; Massa et al., 2001; Lo Duca et al., 2002), which are considered specific antagonists of the citrus leafminer (Bouček, 1988; Schauff et al., 1998; Garcia-Mari et al., 2004). All the recorded alternative hosts can be considered "indifferent" to cultivated plants, being related to a single plant genus or species, which enhances their role as a reservoir of natural enemies.

The incidence of parasitism of *S. petiolatus* and *C. phyllocnistoides* on their relative non-target host was, however, so low (in this study: 2.8% for *S. petiolatus* on *C. pulcherimella,* and 8.3% and 3.3% for *C. phyllocnistoides* on *C. pulcherimella* and *Liriomyza* sp., respectively) that any detrimental effect both on native leafminers and autochthonous parasitoid populations can be excluded.

On the basis of our results we could point out that:

- ❑ the maintenance of natural vegetation diversity in citrus agroecosystems sustains populations of exotic parasitoids providing them with alternative hosts, which allow them to go through the period of scarce availability of the target pest;
- ❑ this "support " effect is, as expectable (Tscharntke et al., 2002), more profitable for species with a larger ecological spectrum like *S. petiolatus*, which can probably move earlier into the crop also thanks to larger populations on spontaneous vegetation;
- ❑ a useful parameter to assess non-target effects of biological control agents is likely to be their incidence on populations of non-target species, more than the width of host range.

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Potential impacts of *Harmonia axyridis* on functional biodiversity

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Abstract: *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) is a predatory coccinellid, native to central and eastern Asia. It has been available in many countries for use as a biological control agent of pest aphids and scale insects. In the USA *H. axyridis* has undergone rapid spread and dramatically increased in number so it is now the dominant species of ladybird in many parts of North America and is adversely affecting functional biodiversity. *Harmonia axyridis* has not been intentionally released in the UK, however in mid September 2004 the first individual was found in Essex (SE England). National surveys were launched to monitor the distribution of *H. axyridis* and native coccinellids. From these surveys it is evident that *H. axyridis* has expanded in range and is thriving in SE England. The arrival of *H. axyridis* in the UK has been met with considerable concern both from ecological and anthropogenic perspectives.

Key words: *Harmonia axyridis*, intra-guild competition, intra-guild predator, invasive species, ladybirds

Introduction

Harmonia axyridis (Pallas) (Coleoptera: Coccinellidae) is a polyphagous predatory coccinellid, native to central and eastern Asia (Kuznetsov, 1997). It has been available in many countries worldwide (Europe, South America, North Africa, Middle East, USA) for use as a biological control agent of pest aphids and scale insects. In the USA *H. axyridis* has been repeatedly released as a classical biological control agent since 1916 (Gordon, 1985) but did not establish until the 1980's. However, since establishment, it has undergone rapid spread and dramatically increased in number so it is now the dominant species of ladybird in many parts of North America (Hesler et al., 2001; Tedders & Schaefer, 1994). In mainland Europe it has been commercially available for both classical and inundative biological control strategies since 1982 (Iperti & Bertand, 2001) and has become established in France, Belgium, Holland, Germany, Luxemburg and Italy. *Harmonia axyridis* has not been intentionally released in the UK, however in mid September 2004 the first identified individual was found in Essex (SE England).

The arrival of *H. axyridis* in the UK has been met with considerable concern both from ecological and anthropogenic perspectives. We recognized that *H. axyridis* should be monitored for a number of reasons:

- to assess whether potential ecological and anthropogenic impacts would be realized in the UK, using North America as a case study;
- because the discovery of *H. axyridis* in Britain provided a unique opportunity to study an invasive species from the time of arrival;

- because the arrival presented the rare opportunity to address a range of evolutionary questions as a Founder population adapts phenotypically and genotypically to equilibrium states under selection (Majerus & Roy, 2005).

In this paper we report on national surveys designed to monitor *H. axyridis* and native coccinellids. Furthermore we consider the potential problems and benefits associated with this species within the context of possible impacts on functional biodiversity.

Materials and methods

The Harlequin Ladybird Survey and the UK Ladybird Survey are collaborative projects designed to monitor the spread of *H. axyridis* across the UK, to assess the status of native ladybird populations, and to determine the impact of the former on the latter.

The surveys were launched on the 15th March 2005 with the activation of two websites: the first for monitoring *H. axyridis* (www.harlequin-survey.org) and the second for recording native UK ladybird species (www.ladybird-survey.org). Both websites have been designed to engage the public to contribute to the survey and so provide general information on ladybirds and enable recording either on-line or using conventional post.

Ladybird records are highlighted as verified or unverified within the database. A verified record is one in which the specimen or a photo of the specimen has been seen and identified by one of the contributing scientists. Recorders are strongly encouraged to seek verification of their record and many have done so. This data enables distribution maps to be plotted and these are updated frequently on the website.

Results and discussion

Records obtained, including photographic evidence pre-dating the initiation of the survey, during the survey indicate that *H.* axyridis arrived in Britain in the spring or early summer of 2004 (Majerus et al., in press). Subsequently it has expanded in range from the south-east of the country (where it predominates in London and the eastern sea-board) westward (Fig. 1).

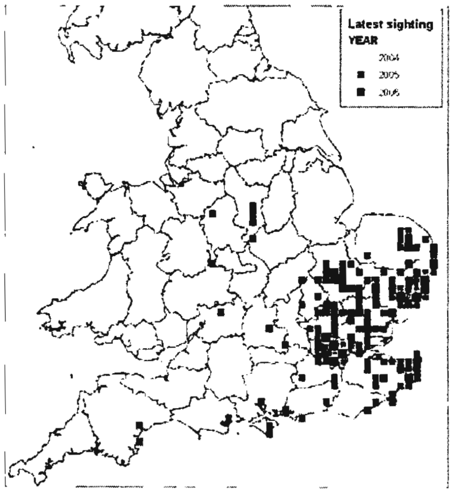

Figure 1. Distribution of *Harmonia axyridis* in the UK (records up to 23rd January 2006).

Aphidophagous and coccidophagous ladybirds are widely considered as important biological control agents and there are examples of their use in all four biological control strategies: classical biological control, inoculation biological control, inundation biological control and conservation biological control. The Australian vedalia ladybird, *Rodolia cardinalis*, marked the advent of modern biological control. In 1888 the vedalia ladybird was released to control cottony cushion scale insects, *Icerya purchasi*, which were devastating the citrus industry of California. The introduction and subsequent establishment of this ladybird resulted in a dramatic decrease in scale insects (Majerus, 1994). There have been many other examples of successful control of scale insects by various ladybird species (De Bach, 1964; Dixon, 2000). However, the control of aphids by ladybirds has largely been unsuccessful (Dixon, 2000) and the release of generalist predators for biological control programmes is contentious for a number of reasons:

- inconsistent and long delays in post-release recovery (LaMana & Miller, 1996);
- potential to outcompete and displace other guild members (Rosenheim et al., 1994);
- impacts on non-target species (Howarth, 1991).

A range of biological attributes (size, diverse dietary range, predatory efficiency and wide niche colonisation ability) associated with *H. axyridis* have contributed to it being considered as a suitable biological control agent but perhaps the most important is that it preys on a wide variety of homopteran insects such as aphids, psyllids, coccids and adelgids (Hodek, 1996; Koch, 2003). The increase of *H. axyridis* throughout the UK may prove to be beneficial in reducing aphid numbers below economically damaging levels within many crop systems and so reducing the use of chemical pesticides. However, the very traits that contribute to the success of *H. axyridis* as a biological control agent are of concern when the wider ecological impacts of this species are considered.

Harmonia axyridis is a generalist predator and so negative impacts on non-target prey species would appear to be inevitable. Furthermore the predators, parasitoids and parasites that surround these prey will also be adversely affected. However, studies on such effects are sparse. There is evidence to suggest that *H. axyridis* is adversely affecting other aphidophages (Sato et al., 2005; Brown & Miller, 1998) through resource competition, intraguild predation and inter-specific competition. Van Lenteren et al. (2003) have developed a methodology for risk assessment for the regulation and release of exotic natural enemies. This general framework considers the host range of a potential biological control agent, its ability to establish, disperse and impact on non-target species. It is notable that *H. axyridis* was allocated a high-risk index when this proposed methodology was applied to it as a biological control agent.

In summary, *H. axyridis* has been shown to be a dominant unidirectional intraguild predator and, although levels of intraguild predation are inversely correlated to aphid or coccid density (Burgio et al., 2002), it has the potential to dramatically affect the functional biodiversity wherever it establishes.

Acknowledgements

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Spatial and temporal variation in carabid seed predation

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Abstract: In this paper we investigated whether spatio-temporal variability in activity-density of granivorous carabid beetles is correlated with seed predation levels observed in the field. We expected that seed predation would be highest in weeks and locations with the highest activity-density of granivorous carabids. As activity-density of carabid beetles is positively influenced by landscape features such as grassy field boundaries, we hypothesized that highest seed predation levels would be found near the field edge. Predation of *Poa annua, Capsella bursa-pastoris, Stellaria media* and *Lamium amplexicaule* seeds was assessed using 'seed cards', which were placed in two organic winter wheat fields at different distances from the edge and changed weekly. Carabids were monitored using pitfall traps. Both seed predation and activity-density of granivorous carabids varied with distance from the field edge and over the season, but the patterns didn't match. Seed predation was lowest by the field edge where carabids were most active, and highest in the field centre where carabid activity-density was considerably lower. Thus high densities of seed predators do not necessarily lead to high levels of seed predation.

Key words: ground beetles, weed seed

Introduction

It is stipulated that the density of carabid beetles in arable land is related to the presence of overwintering sites, such as shrubs and grassy field boundaries. In order to promote carabid densities in some countries it is now practice to create grassy strips inside the fields, so-called 'beetle banks'. Several studies show that carabids can use these newly created habitats for hibernation and dispersal, but few studies relate increased carabid densities to increased pest control (Kromp, 1999).

Modelling studies have indicated that 25-50% seed mortality is generally sufficient to stop or slow down the population growth of annual weeds (Firbank & Watkinson, 1986). Some field studies suggest that these predation levels can be reached by carabids (Honek et al., 2005) but others do not (Westerman et al., 2003b). One factor that may explain some of the observed variability in seed predation by carabids between studies is the variability in carabid density at the farm level (Brust & House, 1988; Honek et al., 2003; 2005). In addition, carabid distribution is variable within fields, often being highest close to the field edge (Kromp, 1999), and species composition changes in course of the season. Therefore the main question of this paper was whether carabid abundance and the amount of seed predation are correlated at field scale. We expected that the pattern of seed predation would follow that of activity-density of granivorous carabids. We assumed that levels of seed predation would be highest close to the field edge, and decrease towards the centre of the field. The temporal variation in seed predation should follow that of carabid activity-density, being highest during weeks when carabids numbers were highest or most active.

Material and methods

The experiment was conducted near Wageningen, the Netherlands (51°58'N, 05°40'E), and was replicated in two fields (designated no. 1 and 2) of organic winter wheat (*Triticum aestivum* L.). Both fields were approximately 2 ha large and were surrounded by 1-3 m wide strips of rye-grass (*Lolium perenne* L.) on all sides.

Per field, seven transects, perpendicular to the field edge and extending 50 m into the field and 1 m into the field margin, were established at 3 or 6 m intervals along the longer edge, so the wheat field extended for at least another 50 m past the edges of the experimental area. Each transects contained five stations, where seed predation and activity-density of carabid beetles were measured: one on the field edge, and four in the field at 4, 11, 24 and 49 m distance from the field edge. Each field also contained five control stations. The experiment ran between 23 March and 27 July 2004.

Seed predation was measured for four species of weeds, which were selected on the basis of attractiveness to spring breeding carabid beetles. Both preferred (*P. annua* [0.43 mg seed^{-1}], *S. media* [0.37], *C. bursa-pastoris* [0.09]) and less preferred (*Lamium amplexicaule* [0.61]) species were included (Honek et al., 2003). In this paper spatial and temporal variation in predation was analysed for data pooled across seed species.

The proportion of seed predation was measured using "seed cards" (Westerman et al., 2003a), each containing 50 seeds of one of the four weed species. Sets of four seed cards (one of each weed species) were nailed to the ground and covered with a wire cage (mesh size 10 × 10 mm), designed to exclude the vertebrates but not the invertebrates. Controls (for measuring background losses of seeds) consisted of sets of four seed cards glued to the bottom of a fine meshed sieve, which was completely wrapped in a fine meshed (1 × 1 mm) cloth, so no predators could enter. All seed cards were changed in weekly intervals.

After exposure to seed predators for 7 days, the number of seeds remaining on each treatment card, N_{cage}, and control card, $N_{control}$, was counted. The percentage seed predation, R, was calculated as the Abbott corrected seed loss per 7 days (Abbott, 1925):

$$R = ((N_{control} - N_{cage}) / N_{control}) * 100 \, [\%].$$

Carabid beetles were sampled using pitfall traps, placed on either side of each cage with seed cards. The traps consisted of 0.5 l jars half-filled with a saturated saline solution as fixative. Pitfall traps were inspected weekly, and data from the two traps per station were pooled.

The spatio-temporal variation in seed predation was analysed using IRREML analysis in Genstat.

Results

The percentage seed predation was not constant with distance from the field edge in either field (field 1: Wald=15.07, d.f=4, p=0.005; field 2: Wald=12.53, d.f.=4, p=0.014) (Fig. 1). In field 1, percentage seed predation increased with distance from the field edge. In field 2, percentage seed predation was highest at 11 and 49 m from the field edge. In contrast, the activity-density of granivorous carabids was highest near the field edge in both fields, and was low at the other locations (Fig. 1).

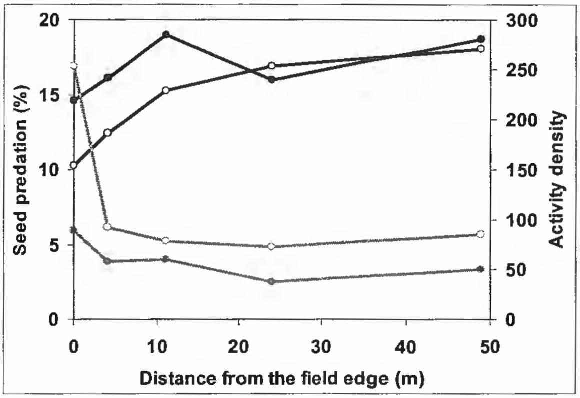

Figure 1. Seed predation and activity-density of granivorous carabids averaged over all sampling dates as a function of distance from the field edge. open circle – field 1; solid circle – field 2; black line – seed predation; grey line – activity-density.

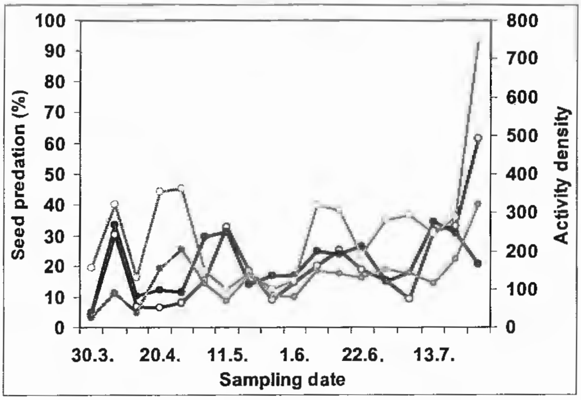

Figure 2. Seed predation and activity-density of granivorous carabids averaged over all distances over the course of the season (spring – summer 2004). The dates represent collecting dates. open circle – field 1; solid circle – field 2; black line – seed predation; grey line – activity-density.

The percentage seed predation varied over the course of the season (field 1: Wald=558.76, d.f=17, p<0.001; field 2: Wald=349.84, d.f.=17, p<0.001), and the temporal pattern was similar in both fields, except in July. Four peaks of seed predation occurred: in early April, early May, mid-late June and mid-late July (Fig. 2). In late July, seed predation patterns differed between the two fields, in field 1 percentage seed predation increased while in field 2 it decreased towards the end of the experiment (Fig. 2). Carabid activity-density also fluctuated during the season, but the pattern was different from that described for seed predation (Fig. 2). Peaks in activity-density corresponded with peaks in seed predation in early April and mid June (both fields) and end of July (field 1).

From these results we conclude that the observed patterns of seed predation and activity-density of granivorous carabid beetles do not match, neither spatial nor temporal.

Discussion

In our experiment, carabids were the only invertebrate seed predators present. Based on the results we reject our null hypothesis, that spatio-temporal variation in seed predation will follow the pattern in activity-density of carabid beetles. We see three possible explanations for the lack of correspondence. First, predators may utilize food patches more efficiently when food is scarce than when food is abundant (Bell, 1991). Secondly, during weeks with high precipitation (weeks 2, 7, 13 and 16 in our study) imbibed seeds may be more easily predated than dry seeds during weeks with low precipitation. Thirdly, changes in the species composition, the phenological state, and the food requirements of the carabids combined may explain why carabid activity-density and seed predation levels do not match.

The results imply that high densities of predators do not assure high weed control. Thus landscape manipulation promoting beneficial organism does not always have to lead towards desired effects in increased weed control.

Acknowledgements

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Impact of low-input plant protection on functional biodiversity in wheat and pea

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Abstract: In a farm of the high-input crop production area Magdeburger Boerde (Saxony-Anhalt) the ecological long-term effects of a low-input plant protection strategy characterized by 50% reduced pesticide usage (50%) in comparison to good plant protection practise (100%) are investigated. In this study, aphid and predator densities on plants (counts) as well as activity densities and diversity of carabids and spiders on the ground (pitfall trappings) were used as bioindicators. This paper presents results from the field-to-field comparisons in the first two years (2004, 2005). In both years in wheat statistically significantly more predator units (especially syrphid larvae) were observed in low-input fields than in high-input fields, whereas in 100% variant nearly all coccinellids were killed in 2005. Diversity index and evenness were not affected (2004). In pea, there was no clear evidence of an advantage of the 50% strategy for predator density and natural control in either year. After two years, no notable cumulative effect of the low-input strategy could be observed. However, in 2005, one of the 50% fields cultivated with pea was colonized by significantly more carabid species.

Key words: insecticide, reduced dose, low input, wheat, pea, predator unit, aphids

Introduction

In Germany, roughly 29,000 t pesticides, equivalent to 1.7 kg active substance per ha, are used each year (Schmidt, 2003). A national Reduction Program Chemical Plant Protection (2004) was established to reduce pesticide input in crop farming. It is presumed that a significant reduction will have in positive effects not only on consumer protection, but also on the ecological situation in agricultural landscapes. Haughton et al. (1999) reported that the diversity and abundance of plants and non-target arthropods increased as the intensity of pesticide use decreased. Several studies have shown that a renunciation of chemical pesticides, e.g. in organic farming, improves regulatory mechanisms and biodiversity in crop fields (e. g. Kromp, 1990; Roschewitz et al., 2005). Regarding national reduction programs, long-term investigations are needed to assess sustainable ecological effects of permanent reductions of pesticide usage in conventional arable farming.

The aim of this long-term study, started in 2004, was to determine the ecological effects of a low-input plant protection strategy (permanently by 50% reduced dosage of applied pesticides) versus conventional plant protection strategy in terms of good plant protection practice (100%). The test fields were located in a high-input arable farming region. The investigations are focused on the tri-trophic systems: wheat-aphids-predators and pea-aphids-predators. The present contribution describes results for the years 2004 and 2005.

Material and methods

The study was performed on a conventional farm in Magdeburger Boerde (Saxony-Anhalt, Germany). Each of three field-to-field comparisons represents the treatments a) plant protection according to good plant protection (100%) and b) low-input plant protection with exactly the half dose of all pesticides used (50%). The sizes of field-pairs (100%/50%) 1, 2 and 3 were: 12.3/7.5 ha, 8.0/7.0 ha, 16.1/7.0 ha. Crops planted in 2004 and 2005 were in field 1: pea – winter wheat, field 2: winter wheat – pea, field 3: spring wheat – winter wheat. Tillage, fertilization and growth regulators applications were the same in both variants.

In wheat, aphids, aphid-specific predators, syrphids, chrysopids and epigeic arthropods were counted on the tillers and on the ground along the drill row. Each survey contained a count of a 2-m drill row (roughly 200 tillers) at 5 counting points (n=5). The counts were performed at end of flowering before insecticide spraying as well as two and three weeks after insecticide spraying, respectively. In pea, 50 plants at each of the five sampling points (n=5) were examined for infestation or non-infestation by *Acyrthosiphum pisum*, and the occurrence of aphid predators (see wheat) was assessed on a 5-m drill row at each sampling point before and after insecticide spraying.

Epigeic arthropods (carabids, staphylinids and spiders) were sampled using pitfall traps 10 cm in diameter filled with 4% formaldehyde and detergent. In both variants, six pitfall traps (n=6) were placed on the middle line of fields with a distance of 50 m to each other. The pitfall traps were emptied once weekly for four weeks, starting on 2004-06-01 and 2005-06-08. The carabids were determined to species level.

The assessed predator densities were converted to predator units (PU) as defined by Freier et al. (1998) to evaluate the overall predator community potential. Statistical analyses included the estimation of standard deviation and significance tests (ANOVA, t-test) using GraphPad Prism 4.01.

Results and discussion

In 2004 cereal aphids (*Sitobion avenae, Metopolophium dirhodum, Rhopalosiphum padi*) infested the wheat fields in extremely high numbers. They were insufficiently reduced by the insecticide in the 50% fields (Table 2). This strategy benefited the occurrence and effect of aphid predators, especially syrphid larvae. Diversity index and evenness were not affected (Table 1). Aphid outbreak was also observed in pea. The aphid densities were not reduced in either variant (Table 2). There was no indication that the 50% strategy had a positive effect on predator densities and effects; however, more carabid species colonized the 50% field.

In 2005, relatively low numbers of aphids infested the wheat field. In the 50% variant, insecticide use did not really reduce infestation but affected the occurrence of beneficials, yet not as strongly as in the 100% fields, where nearly all coccinellids were killed (Table 2). Statistically more predator units were observed in low-input fields than in high-input fields. At low pea aphid infestation levels, there was no clear evidence of an advantage for predators and natural aphid control.

No notable cumulative effect of the low-input strategy was observable after two years. However, in 2005, the 50% pea field was colonized by significantly more species.

In the present investigation, we expected to see positive effects of the low-input strategy on natural control and biodiversity, although other studies showed different findings. Purtauf et al. (2005) found no difference between organic and conventional farming with regard to carabid beetle diversity. These results showed that the ecological state is strongly influenced by different intensities of insecticides, but not of herbicides or fungicides. This was considered in our methodological approach, where sampling was performed before and after insecticide application. Positive effects of 50% treatment could result from higher remaining aphid populations and lower toxicity in predators. Statistical analyses of long-term data will show whether sustainable effects occur and whether conservation of beneficials in low-input fields is an important factor in natural control of surrounding crops.

Table 1. Effect of conventional and low-input plant protection strategies on epigeic arthropods in wheat and pea. Mean ± standard deviations (n=6).

Pitfall trapping		Dose [%]	2004		2005	
			Before spraying	After spraying	Before spraying	After spraying
Wheat						
Carabidae	Individuals per pitfall trap	100	15.9 ± 7.1	2.0 ± 1.5	18.0 ± 7.6	11.5 ± 3.6
		50	13.4 ± 5.3	5.4 ± 3.1	18.2 ± 5.2	4.7 ± 2.7
	Total number of species	100	15	7	In process	In process
		50	16	7	In process	In process
	Diversity index	100	1.58	1.47	In process	In process
		50	1.84	1.43	In process	In process
	Evenness	100	0.59	0.76	In process	In process
		50	0.66	0.73	In process	In process
Staphylinidae	Individuals per pitfall trap	100	7.6 ± 4.9	6.6 ± 4.0	9.6 ± 5.0	1.8 ± 1.6
		50	21.0 ± 9.6	9.9 ± 5.2	16.6 ± 13.9	2.2 ± 1.6
Araneae	Individuals per pitfall trap	100	13.4 ± 4.3	2.1 ± 1.4	16.0 ± 13.0	9.3 ± 4.0
		50	8.6 ± 4.0	6.4 ± 5.3	29.1 ± 18.7	15.0 ± 9.6
Pea						
Carabidae	Individuals per pitfall trap	100	49.0 ± 25.6	9.8 ± 7.9	6.7 ± 6.3	8.6 ± 6.4
		50	65.7 ± 24.9	12.2 ± 10.6	16.0 ± 9.2	20.6 ± 15.3
	Total number of species	100	12	13	In process	In process
		50	18	20	In process	In process
	Diversity index	100	1.40	1.80	In process	In process
		50	1.71	1.69	In process	In process
	Evenness	100	0.57	0.70	In process	In process
		50	0.59	0.57	In process	In process
Staphylinidae	Individuals per pitfall trap	100	0.7 ± 0.8	3.7 ± 2.8	4.3 ± 3.3	19.3 ± 12.3
		50	4.5 ± 1.8	5.9 ± 3.9	7.3 ± 4.4	24.9 ± 21.9
Araneae	Individuals per pitfall trap	100	10.2 ± 5.0	1.3 ± 2.1	13.5 ± 3.8	4.1 ± 3.0
		50	14.2 ± 8.2	3.2 ± 1.8	11.7 ± 4.7	10.6 ± 7.4

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The authors would like to thank the Deutsche Bundesstiftung Umwelt for supporting this project. We also thank Birgit Schlage, Andreas Schober and Ute Mueller (BBA) for their valuable assistance in on-the-site data collection, insect determination and the statistical data analysis. Also, special thanks to Suzyon Wandrey (Berlin) for editing the manuscript.

Table 2. Effect of conventional and low-input plant protection strategies on aphids and their predators in wheat and pea. Mean ± standard deviations (n=5). Significant differences between doses are indicated by different letters (paired t-test, $p<0.05$).

Counting	Dose [%]	2004			2005		
		Before spraying	After spraying		Before spraying	After spraying	
Wheat (field 3/field 3)		BBCH 65	BBCH 75	BBCH 83	BBCH 71/77	BBCH 75	BBCH 83
Aphids per tiller	100	7.8 ± 5.6a	2.0 ± 1.0a	2.1 ± 0.3a	3.1 ± 1.1a	1.1 ± 0.4a	3.4 ± 1.1a
	50	5.5 ± 1.4a	17.4 ± 4.7b	43.6 ± 14.5b	2.2 ± 1.2a	7.3 ± 1.7b	16.5 ± 4.3b
PU per m^2	100	1.63 ± 1.26a	2.96 ± 2.44a	3.76 ± 2.04a	4.95 ± 5.22a	0.70 ± 1.05a	1.24 ± 2.41a
	50	1.10 ± 1.83a	7.70 ± 1.45b	70.96 ± 19.85b	3.30 ± 3.19a	6.32 ± 2.94b	4.94 ± 1.40a
Syrphidae Larvae per m^2	100	1.32 ± 1.40	2.78 ± 2.48	3.72 ± 2.04	0.35 ± 7.82	0	1.08 ± 2.41
	50	0	7.08 ± 1.44	69.59 ± 19.55	0	3.13 ± 3.36	3.19 ± 1.11
C. 7-punctata Adults per m^2	100	0	0	0	3.76 ± 5.32	0	0
	50	0	0	0	2.26 ± 3.23	1.54 ± 2.13	0
Pea (field 1/field 2)		BBCH 33-39	BBCH 69-77		BBCH 55-67	BBCH 71-79	
Infested plants [%]	100	31	81		19	7	
	50	34	98		36	41	
PU per m^2	100	0	0.09 ± 0.19		0.11 ± 0.16	0.28 ± 0.69	
	50	0.19 ± 0.42	0.44 ± 053		0.29 ± 0.29	0.37 ± 0.65	
Syrphidae Larvae per m^2	100	0	0.09 ± 0.19		0	0	
	50	0	0.23 ± 0.33		0.03 ± 0.06	0.03 ± 0.06	
C. 7-punctata Adults per m^2	100	0	0		0.10 ± 0.16	0	
	50	0.19 ± 0.42	0.19 ± 0.40		0.26 ± 0.31	0.16 ± 0.38	

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Multi scale modeling of effective infection pressure from *Phytophthora infestans*

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Abstract: Effective management of potato late blight requires prediction of the risk posed to potato fields from external inoculum sources of *Phytophthora infestans*. BLIGHTSPACE is a spatio-temporal model (parameterized for potato late blight) that has been developed and utilized to study the progress of epidemics in genotype mixtures and in networks of fields. Six different dispersal models were developed and tested against experimental data to determine which would be the most suitable model to provide long-range transport of spores within BLIGHTSPACE; this was found to be a hybrid Gaussian Plume/K-model. Work is ongoing to develop a model for the survival of spores during long-range transportation. These three sub-models will be integrated in the near future to provide an experimental arena for testing various control options for potato late blight.

Keywords: *Phytophthora infestans*, spores, dispersal, survival

Introduction

In modern agroecosystems there has been an increase in the uniformity of plant characteristics, fertilizer use, and plant aggregation in space and time in order to meet a variety of agronomic, harvest, and quality concerns. The end result is often large blocks of genetically and morphologically uniform plants that not only have a narrow genetic base for disease resistance, but also create a stable microclimate favorable for the development of disease. Conversely, many natural ecosystems are less prone to severe epidemics, due to the diversity of host genotypes and their patchy distribution. Spatial diversification of host resistance therefore appears as an important approach in the effort to achieve successful and sustainable management of crop pathogens (Skelsey *et al*., 2004).

The primary objective of this research is to investigate the use of genetic diversification at multiple levels of scale (within and between crop fields) in such a way that effective spatial dispersal of viable spores of *Phytophthora infestans* is minimized, thus reducing the spread and impact of potato late blight (PLB). This will be achieved through the development of a multi-scale, epidemic simulation model, parameterized for PLB.

Theoretical framework and approach

The probability of a viable spore reaching a susceptible host plant depends on several steps: production and release of spores into the atmosphere, long-range transport and deposition of spores, and survival of spores during their flight. In order to create a multi-scale epidemic model for PLB, there was a need to first develop separate models for each step.

Within field epidemic development

BLIGHTSPACE is a spatially explicit, age-structured, integro-difference equation model that was developed to simulate general (blanket) and focal (develop from a point source) epidemics of *P. infestans*, and to explore the effect of heterogeneous genotype mixtures on the development of disease (Skelsey *et al.*, 2004). The model simulates the life cycle of the pathogen, the growth of the potato host plant, environmentally dependent host-pathogen interactions, fungicide applications and the temporal and spatial development of general and focal late blight epidemics for various scales and patterns of host genotypes and with various different dispersal kernels (within field transport). Figure 1 gives some examples of different spatial configurations of host genotypes that can be simulated using BLIGHTSPACE.

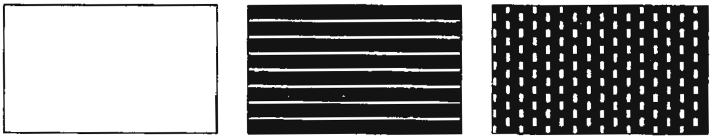

Figure 1. Genotype mixtures created in the model BLIGHTSPACE. White blocks represent plants susceptible to *Phytophthora infestans* and black areas represent resistant plants.

This model was used recently to investigate whether genotype mixtures that are effective in reducing general epidemics of *P. infestans* will likewise curtail focal epidemics (and vice versa). A new genotype connectivity parameter was derived and used to accurately predict changes in the development rates of both types of epidemic for different spatial configurations of host plants and for different dispersal kernels, indeed, Figure 2 shows a high level of correlation in the simulations between *r*, the apparent infection rate in general epidemics, and *c*, the radial velocity of focus expansion in focal epidemics. These results indicate that the spatial arrangement of the host population impacts the development of general epidemics and the spread of focal epidemics by a common mechanism and provide theoretical support for future experimental research efforts aimed at developing globally applicable management strategies based on diversified landscapes / mosaics.

Between field transport

BLIGHTSPACE can also be used to randomly generate networks of host fields, where each field undergoes local epidemic and host development as described in the previous section (see Figure 3). Fields in the network are linked through the long-range dispersal of spores therefore a suitable dispersal model had to be found.

Although many gas and particle dispersal models have been developed by Meteorologists, few of these models have been applied in plant pathology. Different types of models are available with their specific balance between accuracy and practicability. A prime requirement of any atmospheric transport model is predictive skills in the relevant range of spore input levels. BLIGHTSPACE was used to determine the yield (t(DM)/ha) response of potato crops to spore inputs under the influence of variety properties and various fungicide management regimes and with 10 different years of meteorological data as input. Approximately 5,000 epidemics were simulated; the results indicating that some management scenarios were extremely sensitive to spore input therefore an accurate dispersal model from the atmospheric sciences would be required.

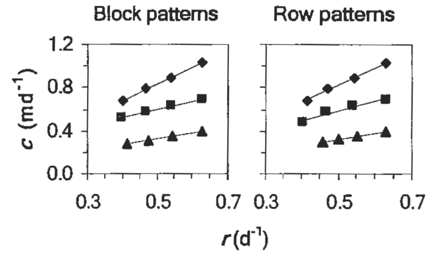

Figure 2. Relationship between apparent infection rate, *r*, and radial velocity of focus expansion, *c* in simulated potato late blight epidemics. ◆ = wide Laplace kernel, ▲ = narrow Laplace kernel, ■ = Gaussian kernel, with mean dispersal distances of 2.44, 0.95 and 2.44 m respectively. The four points in each data set relate to calculations of *r* or *c* at four fractions, *f*, of susceptible plants in the host population: 0.125, 0.25, 0.5, and 1.

Figure 3. Network of fields created in the model BLIGHTSPACE. White blocks represent host fields and black areas represent non-host fields.

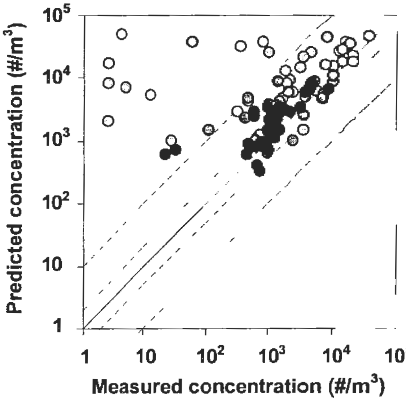

Figure 4. Predicted versus measured spore concentrations. The outer dashed lines mark the limits of a prediction error of factor 10, the inner dashed lines a prediction error of factor 2, and the solid line is a 1 to 1 line. Data points are color-coded from white to black on a grey scale representing increasing distance from the point of spore release.

Six different atmospheric transport models were developed and tested by calculating expected spore concentrations and assessing the goodness-of-fit with experimental data, where spore concentrations were measured above a potato crop at up to 100 m from a point source of *Lycopodium clavatum* spores during 10 minute release sessions (Spijkerboer *et al.*, 2002). The most accurate of the six models tested was OPS-ST (Operational Priority Substances – Short Term). In Figure 4 predictions for spore concentration by this model are plotted against corresponding measured concentrations for ten experimental measurement sessions

Spore survival

Solar irradiance, temperature and relative humidity are the key weather variables that influence the survival of *P. infestans*. In a recent study, solar irradiance has been highlighted as the major factor responsible for reductions in sporangia viability (Mizubuti *et al.*, 1999) and the results of this study will be used to create a simple model for spore survival during between field transportation.

Integration

In the near future, the various sub-models described above will be combined to test the efficacy of various control options against infection pressure from sources in a network of fields, e.g.: spatial separation of susceptible and resistant genotypes at the landscape level; use of genotype mixtures at the field level; evaluation of different separation distances between fields; reduced fungicide dose rates as a function of distance to nearest neighbor and weather conditions. The efficacy of these control options will be compared through their effect on the final potato yield in the network.

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Landscape resources vs. commercial biocontrol agents in the protection of greenhouse sweet pepper – a new exploratory project in Hungary

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Abstract: Western flower thrips (WFT, *Frankliniella occidentalis*) causes the biggest economic damage in greenhouse sweet pepper in Hungary. Effective, adequate, economic and environmentally safe WFT control is unavailable at present. According to our preliminary results, landscape characteristics of a given area determine the abundance of immigrant natural enemies in greenhouses. In some cases, where the greenhouses were surrounded with diverse and moderately disturbed habitats, both chemical and biological control proved to be unnecessary. To make thrips risk assessment more objective, adequate and standardisable, this paper proposes novel landscape evaluating methods like maize silk-shaking or spider web analysis.

Key words: *Frankliniella occidentalis*, *Orius*, *Xysticus*, *Aeolothrips*, *Theridion impressum*, spider web analysis, natural enemies, biological control, greenhouse pepper

Introduction

Sweet pepper is one of the most important greenhouse crops of Hungary, which is grown mostly in monoculture, using conventional technology. This technology induces a series of typical "conventional" pest problems, due to the elimination of natural enemies immigrating spontaneously into the greenhouses. Our experimental studies in the last 5 years proved that producing high quality greenhouse sweet pepper in the Jászság region does not require chemical control. In order to adapt the results of our previous biocontrol studies a further, practice-oriented 3-year project (2005-2007) was started.

Each workpackage of the project supports directly or indirectly the control of western flower thrips (WFT, *Frankliniella occidentalis*), the major pest of greenhouse sweet pepper in Hungary. The project consists of the following workpackages:
1) Landscape resources and risk assessment. Development of a simple, environmentally based risk assessment method in order to determine the potential change of thrips damage if chemical control or commercial biological control would be avoided in a given greenhouse.
2) Applicability of the common crab spider (*Xysticus kochi*) (Fig. 1) against western flower thrips – which is a previous invention of our department (Zrubecz et al. 2004).
3) The influence of agronomic practices (cultivars, pruning, fertilization, mulching, banker plants) on thrips damage.
4) The effect of green manure on soil borne pests (especially nematodes); comparison of efficiency and costs: green manure vs. chemical control.
5) Application of selective control methods against other pests (e.g. aphids, bollworms) in order to favour biological control of WFT.
6) Biological control of soil-born pathogens.

7) Economic evaluation of the applied technologies.
8) Initiation of Farmer's Field School (similarly to FAO FFS system) for pepper growers of the region.

The aim of our paper is to show the preliminary results of the first and second workpackages of the project in 2005.

Material and methods

Sampling the greenhouses

The study involved a total of 66 commercial greenhouses in the following towns or villages: Boldog, Galgahévíz, Gödöllő, Hévízgyörk, Jászfelsőszentgyörgy, Jászfényszaru, Nagykáta, Pusztamonostor and Szentlőrinckáta. Pepper flowers were sampled throughout the growing season (50 flower/greenhouse/sampling date) in parallel with quantitative (damaged surface unit) and qualitative (commercial classes of pepper) thrips damage evaluation. Greenhouses were characterised by the following thrips control types:

1) conventional (application of synthetic insecticides) 30 greenhouses;
2) commercial biological (release of commercial *Orius spp.* and *Amblyseius spp.*) 22 greenhouses;
3) experimental biological I. (release of *Xysticus kochi* spiderlings a) on individually caged plants, true replicates; b) in blocks of plants, true replicates; c) in one greenhouse, where the neighbouring untreated greenhouse served as a control, pseudoreplicates only)
4) experimental biological II. (release of a mixture of arthropods, collected from flowering field margins and alfalfa; one greenhouse, separated to a treated half and a control half; pseudoreplicates only)
5) untreated control, 12 greenhouses;

Sampling the landscape

In the „smaller scale landsape evaluation“ a wide range of habitat patches were sampled in the proximity of greenhouses using a sweepnet. In the "larger scale landscape evaluation" a snapshot sampling (when multiple sites throughout a geographic area are sampled within a short period of time (e.g. flowering period of maize), representing almost the whole region was carried out in *Conium maculatum* plants and in maize fields. Arthropod assemblage of *Conium maculatum* was sampled by beating. Maize fields were sampled by two methods: 1) silk-shaking 2) analysing the web content of *Theridion impressum* (Araneae: Theridiidae). Both methods are novel in landscape evaluation, although web content analysis of *Theridion impressum* was already used in a GMO risk assessment project (Tóth et al. 2004), where habitat quality of *Bt* and non-*Bt* maize plots were compared by counts of prey items in spider webs.

Results and discussion

Preliminary results

Application of *Xysticus kochi* decreased thrips damage significantly ($p<0.05$; Welch test) in the experiments. Damage-decreasing effect of spiders could be explained either by their predatory activity or by their hypothesised repellent effect (their presence on the generative parts of pepper may repel thrips). The necessary dose of spiderlings (number of individuals/plant) for an economically acceptable thrips control could be calculated only in the case of individually caged plants. Repeated release (3-6 days after the first release) of spiderlings in the same dose is more efficient for thrips control than a single release of double dose.

Releasing a "field mixture" of arthropods also decreased thrips damage significantly compared to plants of the control block. This field mixture did not introduce any pests of economic importance into the greenhouse during the experiment. However, it is necessary to repeat this experiment in more greenhouses and applying natural enemies of further fields in different years, because of the potential risk of pest drag-in.

Conventional pest management and commercial biological control had similar efficiency in 2005. Thrips damage in untreated control greenhouses in the hypothesised low-risk area (diverse, moderately disturbed environment) was economically negligible, in contrast to the severe thrips damage in the hypothesised high-risk area (simple environment with frequent anthropogenic disturbance). It confirms the findings of Booij (2003) and den Belder et al. (2003) that landscape quality may have a strong impact on thrips populations.

Maize silk-shaking and the sampling of *Conium maculatum* proved to be a suitable tool for estimating natural enemy resources in this project, since the most important, air-borne thysanopterophagous arthropods (*Xysticus spp.* spiderlings, *Orius spp.* bugs and *Aeolothrips spp.* predatory thrips) are constant elements of arthropod assemblages of maize silk and *C. maculatum* flowers. *Theridion impressum* webs also contained corpses of *Orius spp.* and *Aeolothrips spp.* individuals in good condition (identification was possible), so it can serve as a complementary tool of silk-shaking in landscape assessment.

Expected results of the project

One of the expected direct results of the project is to make the Jászság pepper free of pesticide residues and free of WFT damage in selected greenhouses by introducing an alternative pest management approach and technology. The expected indirect result of the project is that our alternative, region-specific technology would significantly reduce both the pesticide induced health risk of local people and the pollution of the environment. This beneficial effect can be reached by supressing present pest management technology that is based on pesticide fumigation.

The expected scientific result is a series of standardisable methods to assess landscape as a resource for natural enemies.

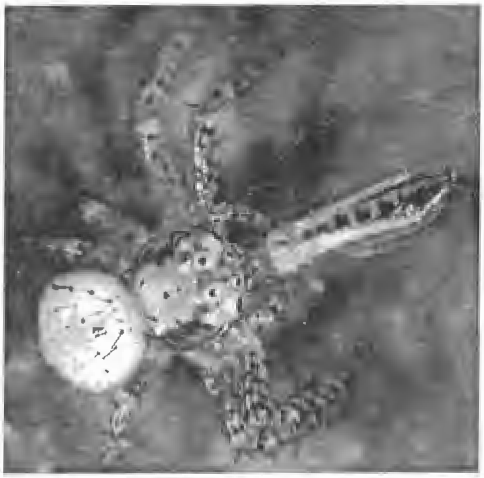

Figure 1. Juvenile crab spider (*Xysticus kochi*) preying on western flower thrips (*Frankliniella occidentalis*) (Photo: A. Nagy).

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Ways to support a natural self-regulation in agrolandscape

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Abstract: Arthropods and plants inhabiting an agrolandscape are very diverse from the biological point of view. Some of them living in forests, forest belts and bushes prefer shady habitats, and their effect on crops is usually insignificant. On the contrary, light-requiring species living in open habitats play a key role in crops. This complex of organisms may be divided into two groups. The first group is represented by arthropods and plants which are able to spread quickly over a territory. This group includes weeds, pests and some well flying predaceous and parasitic insects. They are inhabitants of the whole agrolandscape but not of any certain ecosystems. In particular the pests have to be good migrants due to a crop rotation. Most of arthropods and plants may be attributed to the second group. They are poor migrants and stay at the same places for many years. Such a complex of organisms may inhabit field margins and forest verges covered by natural grassy plants. These grassy plants should not be considered as weeds. They, as well as insects feeding on them, are usually not able to colonise the crop field. However predators and parasites inhabiting the margins can use the field as a foraging territory. If forest verges do not contact directly with the field, they supply only well-migrating entomophagous insects to the crop. Thus, our main aim should be a management of the field margins to provide optimal conditions for natural enemies. Abstract biodiversity indices are useless in this case: we have to comprehend real biology of organisms and interactions between them. The possible ways to increase the stability of the agrolandscape are described.

Key words: agrolandscape, agroecosystem, field margins, biodiversity, pests, natural enemies, weeds

Introduction

The obvious positive correlation between biodiversity and stability of agroecosystems (and also agrolandscapes) was reported by many authors. However it has been supposed (Tshernyshev, 2001) that the ability of an agrolandscape to resist pest outbreaks is not related directly to the biodiversity. Here we propose the possible ways to support the stability of agrolandscape on the base of analysis of the biology of various arthropods and plants including their reactions to the light, ability to spread over the territory and trophic relationships.

An agrolandscape consists mainly of elementary agroecosystems. In its turn, every agroecosystem is divided at least into three different biotopes: the field, field margins covered by various natural grassy plants, and neighbouring parts of the landscape (forest belts, edges of forest, pastures, other fields, etc.). The field margin is a territory adjoined to the field. Vegetation complexes of these biotopes differ very distinctly, whereas there are some common species of arthropods in two and sometimes even in all three biotopes. The paper is based in a great extent on our materials collected in Moscow and Krasnodar regions.

The field

The crop field is colonised every spring by phytophagous and entomophagous arthropods preferring open sunny places. They may be divided in two groups: good and poor migrants. Most of pests, as well as weeds, are good migrants. They are inhabitants of the whole agrolandscape but not of any particular agroecosystem. The same may be said about some entomophagous insects having high migratory abilities (for instance lady-birds, predaceous bugs, some parasitic hymenopterans). Development of the pests takes place usually in the field. The pests have to be good migrants because their food plants are cultivated in other fields every year due to a crop rotation. Hibernation sites of the pests may be situated at a long distance from the fields, sometimes in forests where a layer of debris is thicker and all conditions in winter are more favourable. Indeed some specimens of the pests can hibernate in debris of the field margin but they seem not to be numerous. Well-migrating natural enemies use both the field margins and the forest verges at a great distance from the field as a reservation.

In the field, poor migrants are represented mainly by entomophagous arthropods. Typical examples of such natural enemies are many carabid-beetles, some staphylinid-beetles, small parasitic hymenopterans, almost all spiders. Many of these arthropods use the field, especially its edges, as a foraging territory. They spend a significant part of their life in the field margins.

Almost all plants and arthropods, found in the field and in the field margin, are light-requiring species. The species inhabiting the field may be found in the field margins, on the contrary many arthropods usual in the margins are not able to colonise the field (Tshernyshev, 2001). Arthropods inhabiting the forest belts and other shaded habitats may only occasionally be found in the field margins and moreover in the field.

Field margins

The field margin is the place especially important for the stability of an agroecosystem. Conditions in the margins are favourable for both phytophagous and entomophagous arthropods. As a rule these phytophagans are not able to feed on cultural plants, but they may be a reserve food for natural enemies. Plant debris in the margins attracts many detritophagous arthropods which in their turn may serve as a food for many entomophagans. This debris may be used by arthropods as a shelter. The most of arthropods are not able to live in the field all round the year. Many of them hibernate and develop in the field margins. Some of them use the margins as shelters also during unfavourable weather or after a treatment of the field by insecticides. Hence, the field margin is the main reservation and source of natural enemies for the field. The field margin is colonised by light-requiring arthropods, therefore the presence of any trees or bushes is inadmissible there. Any rubbish and pollution can also be harmful for natural enemies in the margins. Treatment of the margins by insecticides destroys natural complex of arthropods.

There is a widespread opinion that the field margins are the source of weeds. Natural grassy plants typical for late phases of succession are not able to colonise the field as true weeds do. However every treatment of margins by herbicides or ploughing destroys the natural vegetation and then the weeds replace it (the first phase of a geobotanical succession). Full recovery of the plant complex of the field margins is possible only in many years. The succession may be significantly accelerated by sowing natural plants adapted to sunny open spaces (Mirkin & Naumova, 2005).

Therefore the general attention should be attracted to the management of the field margins and preserving them in the most favourable state for the natural enemies.

Ways to support the agrolandscape stability

Arrangement of strips dividing the field

The field margin is only narrow strip of ground around the field. As a result, the number of natural enemies passing on from the margins to the field is limited. Moreover, our results (Tshernyshev, 2001) showed that most of the natural enemies do not reach the central part of a large field. Consequently, the central part of the field is the most favourable place for pest populations, although many of them start to colonise the field in spring from its edges.

The narrow strips sown with natural grass vegetation and crossing the field may well complement to the field margins. Various successes were described (Barrett, 1996; Thomas et al., 1991) but it is clear that a certain term (not less than 2 years) is necessary for an arthropod complex to colonise these strips and to form a stable population there. Artificial "islands" covered with flowering plants may be very useful for feeding of flying parasites (Kovalenkov & Tjurina, 1998).

Arrangement of stacks of decaying straw or hay

The increase of natural enemies abundance is possible also with the help of small stacks or banks made of decaying straw or hay in the field and in the margins (Tsurikov, 2002; Afonina et al., 2006). The stack may be both a good shelter and also a source of additional food for entomophagous herpetobiont arthropods because there are many detritophagous forms there. Larvae of many predaceous insects inhabit often such stacks but their successful development is possible if the straw stacks remain in the same place for many months. Small parasitic wasps (for example Telenominae and Pteromalidae) can use hollow dry stems on the surface of stacks as shelters for the winter period.

Providing natural enemies with alternative preys and hosts

It happens sometimes that the number of pests in the field is too small or their developmental stages suitable for their parasites are absent. For instance, in the South of Russia the shield-backed bug *Eurygaster integriceps* Put. lays its eggs only once in a season, in the second part of May. The most important suppressors of this bug are parasitic wasps Telenominae (Scelionidae). These wasps infest bug's eggs but they have several generations per season, so during the rest of the season they have to search for eggs of other bugs (usually Pentatomidae). Therefore the abundance of these parasites in spring depends on the abundance of their alternative (additional) hosts in the previous season. It is necessary to provide conditions most favourable for the alternative hosts, in particular to supply food plants necessary for these hosts in the field or around it. Egg production of these bugs may depend on the state of their food plant, particularly on the concentration of mineral salts in the soil.

However if the life cycles of the alternative prey (or host) and pest coincide, the former will draw the natural enemies away from the pest and this will result in diminishing the stability of the agroecosystem.

The alternative preys and hosts may inhabit both the field margins and the field. They may feed on weeds and even on cultural plants. In the last case they may be useful for the agrolandscape stability as an additional food for the natural enemies but only in such cases when the feeding activity of these "pests" is not significant from the economical point of view.

If the weeds in the field are not numerous they may also increase the stability of the agroecosystem. Really, the weeds may draw the pests away from the cultural plants. They may be food plants for many alternative hosts and preys. Finally, the flowering weeds may supply hydrocarbons necessary for many parasitic hymenopterans.

Mowing off crops in the neighbouring fields

Mowing off the crop field leads to sharp decrease of phytophagous insects abundance there and entomophagous forms lose their food. If they are good migrants, they can move from a crop mowed off to the neighbouring ones. So after harvesting of alfalfa coccinellid-beetles, some predacious bugs and parasites fly to the neighbouring cotton crop (Nijazov, 1992).

Conclusions

An agrolandscape will be self-sustainable if its agroecosystems are stable. This is possible only on the base of knowledge of the biology of mass arthropod species and their interactions with each other, plants and other organisms. Abstract biodiversity indices are useless for solving of this problem. Ecosystems with low biodiversity may be self-sustained (Begon et al., 1989; Mirkin & Naumova, 2005; Tshernyshev, 2001). Our main aim should be the increase of natural enemies abundance in the crop fields by providing optimal conditions for them, first of all by management of the field margins.

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Improving natural pest suppression in arable farming: field margins and the importance of ground dwelling predators

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Abstract: Overwintering of soil dwelling arthropods and especially carabid beetles was much higher in unmown perennial field margins than in mown grass strips or barren crop fields. Over 200 generalist predators per m^2 were trapped in field margin enclosures after hibernation. Predator exclusion experiments showed that high-density aphid colonies in May were reduced by 49% compared to predator-free conditions, both in field margins and in summer wheat crops. Over a 4 years period, aphid infestation levels in summer wheat and potatoes were 15%-65% lower in a farming system with a network of perennial field margins, compared to a system without field margins. However, Diamond back moth and slug damage in Brussels sprouts were higher in the system with field margins compared to the control system without margins.

Key words: Farming systems, functional biodiversity, predation, overwintering.

Introduction

Habitat management for the conservation of natural enemies of insect pests is recognized as a valuable strategy in sustainable agriculture (Landis et al., 2000; Gurr et al., 2003). Accumulating evidence shows that generalist predators from field margins can contribute significantly to the suppression of insect pests (Sunderland, 2002; Symondson et al., 2002). Here we report on an ongoing study to quantify such effects at the scale of a farming system.

Materials and methods

Experimental system

All experiments and sampling were carried out at the experimental farm in Nagele (NL) in the 'BIOdivers' and 'BIOintensief' systems as described in Van Alebeek et al. (2003). We compare two organic farming systems of six crops and 10 ha each; one system with a network of perennial field margins (21% of total surface) and one system with few margins (5%). Since 2001, pitfall traps, yellow water pans and crop inspections are being used to monitor natural enemies and key insect pests in crops and surrounding field margins (Van Alebeek et al., 2003). Because of the scale of the two systems, replication was not possible, and a full crop-rotation period of six years is required for a statistical analysis. Results from different locations in the two systems within one year, as presented here, are pseudo-replicates and no statistical tests are applicable.

Hibernation in field margins

To quantify the role of field margins for the survival of overwintering, soil-surface dwelling arthropods, we used pitfall traps within small scale enclosures in field margins and in bare soil in crop fields. A wooden frame 1 x 1 meter and 30 cm high was buried 5 cm into the soil, and covered by an insect net (mesh width 1.4 x 1.4 mm). In two corners inside the frame, a pitfall trap (9.5 cm diameter, filled with a 4% formaldehyde solution) was placed, to catch arthropods becoming active after hibernation. Pitfall samples were collected between March 15 and May 1, 2004. Sampling was finished in the field plots when farming activities for the cropping season had to start. Pitfall samples in the unmown, biodiverse field margins were continued for another three weeks (end of May). Samples were stored in 70% ethanol at 5°C and sorted and counted into functional groups. Three enclosures were placed in unmown, species-rich perennial field margins, three enclosures in short-mown grass strips, and six enclosures in bare soil plots in the field.

Predator impact on aphid infestations

Early season aphid mortality in summer wheat is difficult to assess due to low densities of the founding colonies. Predation pressure was therefore measured by an exclusion technique and an aphid banker plant system. Polyvinylchloride rings (47 cm diameter, 30 cm high) were buried 5 cm into the soil and left open on top. Inside, one pitfall trap (9.5 cm diameter, filled with a 4% formaldehyde solution) was placed to remove any soil-surface dwelling predators. Flying insects and parasitoids and most spiders had free access. Commercially available summer wheat seedlings infested with cherry-oat aphids (*Rhopalosiphum padi*) (Aphibank, Koppert Biological Systems, NL, www.koppert.nl) were used to measure predator impact. After 14 days of predator trapping, a small plastic pot (5 cm diameter) with wheat seedlings and aphids was buried inside the ring, and a similar pot with seedlings and aphids was buried at 20 cm distance outside the ring. A sample of wheat pots was taken to the laboratory to assess the number of aphids in each pot at the start of the experiment. After one week exposure, all pots were taken to the lab and remaining aphid numbers were counted. Six rings were placed in field margins with approximately 25 species of grasses and perennials, and 14 rings were placed in an adjacent summer wheat field. Summer wheat was sown on March 12, predator trapping started on May 13, the introduction of aphids was on May 27, and assessment of the number of aphids remaining was done on June 3, 2004.

Pest suppression in different crops

During 2002 – 2005, crops were inspected two or three times per season, at periods of key pest population peaks. Small plots at 5, 15 and 50 m from the field edge were sampled. Plants were inspected for all pest stages and natural enemies that could be observed on the plants. We compared pest counts in fields of different sizes surrounded by field margins (see Van Alebeek et al., 2003 for details) with control fields in the BIOintensief system of 1 ha with only one side bordered by a grass strip.

Results and discussion

Hibernation in field margins

Unmown field margins are attractive overwintering sites for a range of organisms, especially Carabid beetles. Twice as many carabids survived in field margins compared to field plots without vegetation (Table 1). Generalist predators (carabids, spiders, some rove beetles) hibernate in field margins in densities of at least 150 predators per square meter. But bare field plots also yielded considerable numbers of surviving predators, approx. 100 per m^2. Prolonged trapping in the unmown field margins indicated that, after 10 weeks (by the end of May), more than 540 arthropods (of which over 200 predators) per square meter survived wintertime (data not shown). It is assumed that after May still many more arthropods may become active out of hibernation. Overall arthropod and predator densities are well within the ranges reported by others, e.g. Pfiffner & Luka (2000) and Frank & Reichart (2004).

Predator impact on aphid infestations

Predators appear to be responsible for almost 50% mortality after one week exposure (Table 2). This indicates the potential impact of predators on the colonising phase of aphid

Table 1. Average numbers of soil-surface dwelling invertebrates caught in pitfall traps within 1 m^2 enclosures in different farm habitats during 7 weeks in early spring (March-May), 2004.

	Unmown, biodivers field margins (n=3)	**Short mown grass strips (n=3)**	**Bare soil plots (n=6)**
Carabid beetles	101	33	48
Spiders (all families)	35	59	33
Rove beetles (*Staphylinidae*)	66	32	71
Other beetles	112	45	36
Remaining groups	47	32	13
Total catch per m^2	361	200	201

Table 2. Average numbers of aphids surviving after one week exposure in enclosures from which predators were removed and with free predator access (end of May, 2004).

	n	**# aphids surviving[1]**	**% mortality due to predation**	**# predators removed per ring[1]**
Before the experiment	8	230 ± 78		
In field margin, predators removed	6	172 ± 130		46 ± 22
In field margin, predators free access	6	88 ± 31	49%	
In wheat, predators removed	14	134 ± 57		39 ± 22
In wheat, predators free access	14	68 ± 61	49%	

1: mean ± standard deviation

infestations in spring. The effect of ground dwelling predators on aphid mortality is higher than found in other studies (21% in Holland & Thomas, 1997; 35% in Collins et al., 2002 and 15% in Schmidt et al., 2003). This may be due to the high aphid densities on the banker plants, which normally do not occur under field conditions by the end of May.

Pest suppression in different crops

Monitoring key pests at peak densities (summer wheat and potatoes in July, Brussels sprouts in August or September) revealed that aphid densities in summer wheat were 30% - 50% lower in the BIOdivers system with field margins as compared to the BIOintensief system without margins (Table 3). For aphids in potatoes, densities were 15% - 65% lower in the presence of field margins than without margins. Sunderland (2002) reviewed studies on predation impact and reported 28%-86% aphid reduction in wheat and 80%-88% aphid reduction in potato. We hypothesize that early season predation as shown in the exclusion experiment is an important factor in reducing aphid population pressure. However, in some other key pests, such as Diamond back moth (*Plutella xylostella*) and slugs in Brussels sprouts, the effect of field margins on pest control appears to be negative. Slugs (data not shown) may be stimulated by a better survival and a favourable microclimate in the margins, whereas Diamond back moth may react to increased crop edge length of the smaller plots, divided by field margins, in the BIOdivers system.

Table 3. Key pest densities in three crops in 2002 – 2005 in the BIOdivers system with field margins compared to the BIOintensief system without margins.

	2002	2003	2004	2005
	Aphids in summer wheat (% shoots infested)			
With field margins	13,0 ± 4,4	16,1 ± 10	30,9 ± 8,1	35,3 ± 12,6
Without field margins	24,1 ± 4,3	26,7 ± 5,8	43,5 ± 11,3	57,3 ± 10,9
% aphid reduction	*46%*	*40%*	*29%*	*38%*
	Aphids in potato (% shoots infested)			
With field margins	5,4 ± 2,6	24,8 ± 13,2	58,3 ± 14,2	17,3 ± 12,8
Without field margins	15,2 ± 6,9	43,3 ± 12,3	68,3 ± 9,6	37,3 ± 11,6
% aphid reduction	*65%*	*43%*	*15%*	*54%*
	Diamond back moth in Brussels sprouts (# caterpillars / plant)			
With field margins	---	4,3 ± 2,3	1,8 ± 1,7	0,8 ± 0,5
Without field margins	0,5 ± 0,3	1,9 ± 1,0	1,3 ± 0,6	0,7 ± 0,4
% caterpillar increase	---	*130%*	*32%*	*18%*

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A region-wide experiment with functional agrobiodiversity (FAB) in arable farming in the Netherlands

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Abstract: The background, objectives, stakeholders and first results of a large-scale project on functional biodiversity in the Hoeksche Waard region in the Netherlands are presented. Perennial field margins and annual flower strips on 400 ha of arable farming are being monitored to demonstrate their stimulating effects on natural enemies of aphid and caterpillar pests in wheat, potato and Brussels sprouts. Pest densities, pesticide applications, crop yield and quality, and costs and benefits are being monitored. The project is embedded in a number of region-wide initiatives on biodiversity management, multifunctional agriculture and sustainable rural development. Communication between the multitudes of stakeholders may be a key factor determining the outcome of this experiment.

Key words: sustainable agriculture, natural pest control, field margins, farmers' experiences.

Introduction

Agricultural intensification has led to a dramatic decline in biodiversity in north-west Europe (Robinson & Sutherland, 2002). This in turn has led to increasingly stringent legislation to control environmental pollution and to slow down further decline of wildlife and flora. The Netherlands' Ministries responsible for nature management, water management and environment issued several plans and regulations on pesticide use and water management in agriculture (LNV & VROM, 1991; V&W et al., 2000). In addition, several environmental labels were developed for sustainable agricultural production (Manhoudt et al., 2002).

These developments stimulated the Dutch Federation of Agricultural and Horticultural Organisations (LTO-Nederland), to write a project proposal 'Functional Agrobiodiversity' to prove how effectively crops can be protected by natural disease and pest suppression methods. The goal is to make optimal use of the ecosystem functions for natural pest control (Gurr et al., 2003), and to link multifunctional agriculture to a sustainable development of rural areas. This is not just a scientific and/or agricultural question, but also a social, economic and political challenge (Firbank, 2005; Lovell & Sullivan, 2006). In 2004, a pilot 'Functional Agrobiodiversity (FAB)' (www.lto.nl/fab) was set up jointly with LTO, the Ministry of Housing, Spatial Planning and the Environment (VROM) and the Ministry of Agriculture, Nature Management, and Food Quality (LNV), in the Hoeksche Waard region.

Hoeksche Waard Region

The Hoeksche Waard (population: 83.000) is an island south of Rotterdam in the Province of South Holland in the Netherlands. The Hoeksche Waard consists of polders, reclaimed gradually after the Saint Elisabeth flood of 1421. As a result, dikes, lined with houses and trees, are a key feature of the landscape. The quiet, open landscape in between the dikes contrasts strongly with the densely populated cities of Rotterdam and Dordrecht, located nearby. Also important are the networks of small rivers (creeks) and ditches on the island, which originally were connected with the sea. The largest part of the Hoeksche Waard is used for agriculture, with sugar beet, potatoes, winter wheat and pastures as the main crops.

The dikes, creek banks and woodlots in de Hoeksche Waard together constitute a network of potential sources of natural enemies. However, current vegetation management is not optimal for FAB (Alebeek & Clevering, 2005). In winter time, the vegetation of most dikes, road verges and ditches is too short to provide sufficient shelter to ground dwelling predators. In summer time, only few flowering species can provide nectar and pollen for natural enemies. Thus, a priority of the project is to convince the regional Water Board (Waterschap Hollandse Delta) and other stakeholders to change their vegetation management into a regime of annual mowing and removal of cuttings. In the longer term, this should result in more flowers in summer and more vegetation cover in winter time.

The FAB project

Aim of the project is to develop and improve farming systems based on FAB strategies for pest control at the farm and regional level. Five neighbouring arable farms, with a combined surface of 400 hectares, participate in the project. Farmers, advisors and scientists jointly formulated FAB strategies in wheat, potato and Brussels sprouts. A total of 9500 m of perennial field margins were sown alongside ditches, as hibernating sites for natural enemies. Flower strips were sown over 5000 m alongside and through crop fields. Flower mixtures were specifically designed to provide nectar and pollen for natural enemies, (e.g. parasitoids and hoverflies), without stimulating potential insect pests (Wäckers et al., this volume).

Farmers were compensated financially for the crop surface lost to field margins and flower strips and for the hours invested in margin management and project discussions. Farmers were also advised on the choice of crop protection products, to minimize negative side effects on natural enemies. An agricultural advisory officer (DLV adviesgroep b.v.) is responsible for the coordination and communication between the project participants.

A monitoring programme is carried out by the Netherlands Institute of Ecology (NIOO), Plant Research International (PRI) and Applied Plant Research (PPO-AGV). Flower availability, natural enemy and key pest densities, crop damage and quality, the number of pesticide treatments, and costs and savings of the different measures are being measured.

Results in the first season 2005

In 2005, natural enemies (parasitoids, hoverflies and predatory bugs), were generally more abundant nearby flower strips than further into the crop. In some fields, aphid densities were lower close to the field margins than in the centre of the crop. However the effects of field margins and flower strips on pest populations were not very prominent. A more concentrated network of margins and flower strips seems necessary for significant pest suppression effects.

Using pitfall traps for soil dwelling predators, we found huge differences in densities of carabid beetles between farms. Activity-densities in flower strips varied between 180 carabid beetles per m^2 per 14 days trapping period on one farm, versus 20 beetles per m^2 on another farm. Highest activity-densities were found on an integrated farm (using selective pesticides). Lowest densities coincided with a farm using broad-spectrum pesticides in an intensive spraying programme. This suggests a potential for on-farm management of biodiversity.

These first year's results are a first step towards developing a protocol for deploying biodiversity as a means of pest control. The challenge of the FAB project is to document how natural enemy densities contribute to the suppression of insect pest populations in field crops. In 2006, the surface of field margins and flower strips will be increased and concentrated on specific crop fields, to compare effects with and without field margins and flower strips.

Towards a region-wide Biodiversity Experiment

Alongside the FAB project, several other initiatives are being developed, in which the Hoeksche Waard acts as a focal point. The VROM Ministry and the Province of South Holland launched a programme "Biodiversity in the Hoeksche Waard: for and by citizens", to encourage public participation in environmental policy (Novio Consult, 2005; Wiersema & Alebeek, 2006). The residents of the Hoeksche Waard (farmers, citizens, policy makers, and scientists) formulated more than 30 projects on how nature could be integrated in agricultural and rural development and vice versa. The local agricultural community proposed a plan for 'Sustainable agriculture in the Hoeksche Waard' by 2015, focusing in particular on the functional aspects of agrobiodiversity. Results were translated into a regional Biodiversity Action Plan (BAP), supported by VROM with additional project funding (Van Geel, 2006).

One of these projects resulted in a regional agri-environmental scheme for the establishment of field margins along ditches. The Province of South Holland, Town Councils, the Water Board (Hollandse Delta) and a farmers' organisation for nature management (De Rietgors) together realized 200 kilometres of field margins along watercourses in 2005. The objectives of these margins is manifold: to reduce pesticide drift and nutrient run-off to surface waters, to provide hiding places and foraging area for wildlife and farmland birds, to offer walking tracks and an attractive landscape for recreation, and to support natural pest control by stimulating natural enemies. Future plans include the realisation of an extra 2000 kilometres of field margins along all watercourses in the Hoeksche Waard. This will be the first region-wide field experiment of natural pest suppression in the world.

Scientific support for the development of plans is provided by the Alterra research institute (Wageningen) through two studies of the opportunities presented by the existing network of streams and dikes in the Hoeksche Waard (Geertsema et al., 2004) and optimal management strategies for landscape elements and vegetations as supporting structures for natural enemies. A Wageningen UR research programme on soil biodiversity and nutrient management will also link up with the FAB project in the Hoeksche Waard region in 2006.

Communication essential

Many stakeholders participate in the project, each with their own objectives and expectations. Results from the FAB project can be expressed in many different ways and criteria in order to meet the different stakeholders and their expectations. But as said in the start, projects like this do not simply concern agricultural or scientific maters, but also address social, economic and political issues.

The participating farmers in the FAB project have to adopt new crop protection strategies and practices. Suppliers of crop protection products are challenged to supply products that fit into a strategy of conservation of natural enemies. Scientists and farmers have to develop common views and learn to communicate about complex processes as well as plain field practices. Risks, costs and profits of different options often are unknown and cannot always be weighted in comparable units. Therefore, good communications and exchanges of views and ideas are essential for support and the success of the project. Sustainable production is not simply an imposed package. As situations and conditions change, so must our constructions of functional biodiversity change. It must become a process of learning and perpetual novelty.

Perspective

Although clear results of the Hoeksche Waard FAB project are not yet available, already two new FAB projects for other regions in the Netherlands are being prepared. Field margins can serve different functions at the same time, and therefore bring together many stakeholders in a region.

Projects like this start with relative simple measures as the realisation of field margins, but tend to develop gradually into sustainable development of rural areas. Nowadays, there is political, agricultural and public support for projects on functional biodiversity. Nevertheless, clear successes in terms of significant pest suppression, reduction in pesticide applications, savings for farmers, and improved water quality, have been few sofar. If functional biodiversity is to become an integral part of sustainable agriculture, then we have to deliver hard data on the potentials and limitations of this strategy. Interactive participation of (local) stakeholders in decision making during all stages of the project is crucial for success.

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The influence of local and landscape characteristics on insect pest population levels in viticulture

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Abstract: Ecological compensation areas are thought to play a role in the control of certain pests. Population levels of vine pest insects *Empoasca vitis*, *Scaphoideus titanus* (homoptera, cicadellidae), *Lobesia botrana* and *Eupoecilia ambiguella* (lepidoptera, tortricidae) were monitored using 'Tri-Δnglué' traps and larval countings. Landscape structure was analysed using a geographical information system. The relative abundance of *L. botrana* was positively correlated both with % of vine inside a 100m buffer around the trap and age of the vineyard. This positive response suggests it to be a functional specialist responding to vine resource density. *E. vitis*, a generalist feeder, was more numerous in diversified landscapes. Increasing buffer size resulted in increasing correlation strength up to at least 500 m for both species. *E. ambiguella* and *S. titanus* did not show clear responses to local or landscape parameters. These preliminary observations will enable us to improve our experimental design to better understand the factors determining these insects' distributions. The influence of landscape seems significant but might be through a direct influence on the pest species rather than through predation pressure.

Key words: viticulture, *Empoasca vitis*, *Lobesia botrana*, *Scaphoideus titanus*, *Eupoecilia ambiguella*, landscape, geographical information system, France.

Introduction

The influence of landscape on pest insects is often described in terms of ecological compensation areas (ECA, Boller et al., 2004) increasing predation pressure (functional biodiversity). However, local and landscape characteristics may directly influence the pest through ECA harbouring alternative host plants or acting as physical barrier to dispersion.

Vine plots seem to have a varying vulnerability to the pest insects *L. botrana*, *E. ambiguella*, *E. vitis* and *S. titanus*, which have varying ecological traits: mono to tri-voltine, pure specialist to generalist, sedentary to highly mobile (Stockel, 2000). Here, we present preliminary results that will be used to determine an appropriate methodology and scale for investigating relationships between pest insect relative abundance and local and landscape characteristics.

Material and methods

Experimental sites

70 vineyard plots (Merlot or Cabernet Sauvignon) in the 'Pessac-Léognan' (PL) area and 40 plots (Cabernet Franc) in the Saumur-Champigny (SC) area were sampled. Plots were at least 1 ha and at least 300 m apart. Management was entirely left to the owners.

Insect monitoring

Adult insects were monitored using Tri-Δnglué® traps (a yellow delta 2 μg pheromone trap).

In PL and SC, 1 trap per plot with *L. botrana* pheromone was positioned on the top trellis wire at least 50 m from the plot border. In SC a second trap with *E. ambiguella* pheromone was positioned 50 m from the first. Traps were monitored three times per week from April until September 2005. Pheromone and sticky base were changed every other week.

Larvae were monitored during the first generation population peaks: 200 leaves were sampled for leafhoppers (SC and PL), 50 bunches of grapes were also sampled for tortricids (PL only). Second larval generations were not monitored because of insecticide applications.

Table 1. Spearman's correlation coefficients (r) among insect parameters (species and generations in each area. -- = not measured. Sign.values in **BOLD** ($\alpha=0.05$, bilateral test). Upper right half: data for Pessac-Léognan (n = 70). Lower left half: data for Saumur-Champigny (n = 40).

		PESSAC LEOGNAN									
SAUMUR CHAMPIGNY	**INSECTS**	***LbaG0***	***LbaG1***	***LbaG2***	***LblG1***	***EaaG0***	***EaaG1***	***EvaG0***	***EvaG1***	***EvaG2***	***EvlG1***
	LbaG0		**0.88**	--	**0.88**	--	--	**-0.46**	**-0.36**	-0.11	-0.17
	LbaG1	**0.84**		--	**0.81**	--	--	**-0.46**	**-0.29**	-0.02	-0.20
	LbaG2	**0.79**	**0.92**		--	--	--	--	--	--	--
	LblG1	--	--	--		--	--	**-0.53**	**-0.40**	-0.23	**-0.31**
	EaaG0	-0.01	-0.13	-0.17	--		--	--	--	--	--
	EaaG1	-0.13	-0.16	-0.22	--	**0.48**		--	--	--	--
	EvaG0	0.10	0.22	0.28	--	0.02	-0.08		**0.56**	0.23	**0.67**
	EvaG1	**-0.40**	-0.25	-0.22	--	-0.13	-0.00	0.12		**0.59**	**0.36**
	EvaG2	-0.25	-0.22	-0.18	--	-0.13	-0.16	-0.12	**0.60**		0.22
	EvlG1	-0.25	-0.15	-0.14	--	-0.03	0.24	**0.40**	**0.32**	0.05	
	Sta	0.12	**0.42**	**0.40**	--	-0.23	-0.20	**0.38**	0.19	0.01	0.20

Geographical Information System

A GIS was created with ARCGIS 9.0 (ESRI) using high-resolution ortho-rectified aerial photographs (BD-Ortho®, ©IGN Paris-2002) and interviews with growers (vineyard age, grape variety etc.) A system of habitat classification was defined as follows: vine, potential ECA (forest, garden, grassland) and non-ECA (roads, buildings, waterways).

Inside a 100 m-radius buffer all landscape elements were mapped and groundtruthed. In the area between 100 and 500 meters from the trap, potential ECA habitats and vineyards were mapped using aerial photographs only.

Data analysis

Insect relative abundances were summed within each generation (*Lobesia botrana* spring adult Generation = *Lba*G0, first larval generation = *Lbl*G1 etc.). 3 local (plot surface, planting density, age) and 4 landscape parameters (% vine, % of ECA, % non ECA, number of landscape types), were calculated for buffers of 100 m around the trap and compared to each of the insect parameters using nonparametric (Spearman) Correlation Coefficients (CC).

Results and discussion

Insect dynamics

Insect trappings showed classic population dynamics in both SC and PL (data not shown). *L. botrana* and *E. vitis* were observed in all plots. *S. titanus* was observed in > 50% of all plots in SC, but was rare in PL due to imposed -Flavescence dorée- sprayings in 2004.

As expected (Table 1), strong correlations appeared between successive generations of *L.*

botrana in both sites (Spearman's r ≅ 0.8). *Lb*lG1 was highly correlated with preceding and following adults. This seems to confirm relatively sedentary 'plot specific' population levels that have a 'stable' spatial distribution over a growing season.

E. vitis showed significant correlations between immigrating adults (*Ev*aG0) and subsequent larvae (*Ev*lG1) and between G1 and G2 adults. CCs of G1 larvae and adults were weak confirming the hypothesis that many G1 adults migrate (Decante & van Helden, 2006). *E. ambiguella*, (SC), showed significant CCs between G0 and G1.

Significant negative correlations were observed when comparing *L. botrana* with G0 and G1 of *E. vitis*. Direct inter-specific competition seems unlikely (phloem vs berry feeders), this might indicate opposite responses to habitat features. *S. titanus* shows several positive relationships with *L. botrana* suggesting similar habitat preferences.

Table 2. Spearman corr. coef. (r) among insect abundance, local and landscape parameters in the 100 m buffers. Sign. values in **BOLD** (α=0.05, bilateral test).

		LANDSCAPE IN 100 M BUFFER				**LOCAL**		
	INSECTS	**% vine**	**% ECA**	**% Non ECA**	**Number of landscape types**	**Plot Surface**	**Planting density**	**Planting year**
SAUMUR CHAMPIGNY	**_Lba_G0**	**0.53**	**-0.37**	-0.27	-0.05	-0.07	**0.28**	**-0.40**
	_Lba_G1	**0.32**	-0.19	-0.07	-0.14	-0.23	**0.37**	**-0.38**
	_Lba_G2	**0.33**	-0.19	-0.18	-0.12	-0.14	**0.36**	**-0.38**
	_Eaa_G0	0.10	-0.06	-0.12	-0.12	0.13	-0.20	-0.14
	_Eaa_G1	-0.15	0.14	0.02	0.03	-0.05	0.06	0.01
	_Eva_G0	-0.21	0.26	0.17	**0.35**	-0.08	0.12	-0.20
	_Eva_G1	-0.16	0.03	0.31	**0.35**	0.04	-0.24	0.22
	_Eva_G2	0.24	-0.30	-0.02	-0.01	0.07	-0.14	0.24
	_Evl_G1	**-0.37**	**0.43**	0.09	0.24	0.15	-0.07	0.22
	Sta	-0.20	0.14	0.236	**0.32**	-0.01	0.29	-0.04
PESSAC-LEOGNAN	**_Lba_G0**	**0.39**	**-0.38**	-0.04	**-0.38**	0.22	**-0.25**	-0.12
	_Lba_G1	0.23	-0.21	-0.02	**-0.27**	0.23	-0.06	**-0.26**
	_Lbl_G1	**0.30**	**-0.30**	-0.02	**-0.32**	**0.28**	-0.24	-0.09
	EvaG0	-0.22	**0.24**	-0.05	0.16	-0.14	**0.26**	0.22
	_Eva_G1	**-0.31**	**0.31**	0.01	0.24	-0.15	0.22	0.15
	_Eva_G2	-0.11	0.13	0.01	0.03	-0.18	0.04	-0.02
	_Evl_G1	0.00	0.00	-0.18	-0.09	0.03	0.02	0.00

Insects and Landscape in 100 m buffer

In the 100 m-radius buffers *L. botrana* correlated positively with the surface area planted with vines (strongest for G0) and plot age (Table 2). This indicates a positive response to resource density. Due to interdependence negative correlations with % of ECA occurred.

Adults and larvae *of E. vitis* G0 and G1 were most often negatively correlated with '% of vine' and positively to '% of ECA' and 'Nr of landscape types', possibly due to alternative hosts in nearby vegetation (Decante & van Helden, 2006). For *E. ambiguella* and *S. titanus* data showed no significant results.

Influence of buffer size

When varying buffer size (100, 200, ….. , 500 m) for the most important variable '% of surface planted with vines' (table 3) CCs clearly increased for *Lb*aG0, *Lb*lG1 and *Lb*aG1 in PL (Table 3). For *E. vitis* a similar, but less pronounced increase seemed to occur.

These results suggest that a grain size of at least 500 meters is needed to explain the relationship between *L. botrana* distribution and landscape structure which is much larger than expected considering adult mobility (Torres-Vila et al., 1997). This could indicate that predation, related to (more mobile) natural enemies could be influencing population levels. For the very mobile *E. vitis* G1 adults we did expect the observed influence of large buffers, but results seem to suggest that all adult generations are relatively mobile.

Table 3. Influence of buffer size on Spearman correlations (r) for '% of vineyards' in buffer (data for PL only) and insects. Sign.values in **BOLD** (α=0.050, bilateral test).

	PERCENTAGE OF VINEYARDS IN BUFFER SIZE OF:				
	100 m	**200 m**	**300 m**	**400 m**	**500 m**
***Lba*G0**	**0.39**	**0.43**	**0.50**	**0.54**	**0.59**
***Lba*G1**	0.23	0.22	**0.32**	**0.37**	**0.44**
***Lbl*G1**	**0.30**	**0.35**	**0.45**	**0.49**	**0.56**
***Eva*G0**	-0.22	**-0.27**	**-0.38**	**-0.43**	**-0.46**
***Eva*G1**	**-0.31**	**-0.31**	**-0.37**	**-0.38**	**-0.42**
***Eva*G2**	-0.10	-0.13	-0.16	-0.15	-0.23
***Evl*G1**	0.00	-0.07	-0.11	-0.14	-0.17

Experimental set-up

Weekly observations of adults are sufficient. In future experiments larval counts will be done more precisely (larger samples or several observations). Other derived insects parameters (e.g. ratio between generations) will also be tested. Observations of natural enemies will be done to estimate their presence and impact. Logically they should be related to both pest-population levels (especially for specialists) and landscape (especially for generalists, landscape providing alternative food and shelter).

Landscape definition needs to be improved. Aerial photos seem to be a sufficient basis but habitat definitions should be based on more objective and quantitative criteria such as vegetation layers in each polygon (% of herbaceous ground cover, shrubs, trees). Parameters such as 'contagion' and 'edge' metrics and spatial parameters such as isolation should be tested.

This first year of observations showed that landscape characteristics do correlate with pest insect levels. Since the main species respond to landscape structure at a large scale (> 500 m), monitoring traps will be placed at greater intervals in future experiments.

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The impact of floral resources on syrphid performance and cabbage aphid biological control

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Abstract: We investigated the impact of floral resources on syrphid fitness parameters and on biological control of cabbage aphids. The work led us to the following conclusions:

Honeydew of cabbage aphids enhances the survival of the hoverfly *Episyrphus balteatus*, and can be an important food source when the syrphids are searching within the crop for oviposition sites.

Syrphids can only reproduce when pollen is available as well. Feeding on pollen and nectar during the pre-ovipositional period allows the females to produce eggs for a week thereafter, even when flowers are no longer available. This shows that they can store their food reserves for several days. Female syrphids probably focus on flower foraging during the first week after emergence, before switching to searching for aphids and oviposition sites (in the crop). Thereafter, the syrphid will have to travel again between floral patches and aphid patches to maintain egg maturation.

Cage experiments show that the syrphid *E. balteatus* can be an effective predator of cabbage aphids on Brussels sprouts. The resurgence of the cabbage aphids in autumn, when natural enemies such as syrphids virtually disappear, suggests that these natural enemies play an important role in keeping the aphids under control during summer.

Syrphids are stimulated in the crop by the vicinity of flowering plants like buckwheat and cornflower. During summer the differences in syrphid densities were not reflected in aphid population levels. Possibly, natural enemies that are less dependent on floral resources, such as parasitoids, compensate for the small scale differences in syrphid predator density.

Key words: conservation biological control, natural pest control, field margins, companion planting, functional agrobiodiversity, flowers, pollen, nectar, honeydew, predator

Introduction

Many insect carnivores that can play a role in the suppression of pests require nectar or pollen during their adult life stage (Wäckers et al., 2005). The scarcity of flowering plants in modern agricultural fields may therefore prohibit an effective performance of these beneficial insects (Winkler et al., 2005). Providing these floral resources in the agricultural landscape may therefore be an essential element to improving natural control , but may not always be sufficient (Wäckers et al., 2005). As part of a multifarm field experiment in the Netherlands, labelled as the Functional Agro Biodiversity (FAB) project (Van Alebeek et al., this volume), field margins are sown with a crop-specific mixture of annual flowering plants, to provide these floral resources for the natural enemies of our pests (Wäckers et al., this volume).

To optimize the use of flowering field margins, information is required about the biological control agents and their interactions with food sources and pest species. Firstly, we identify which natural enemies can be effective against the economically important pests in the various crops. Secondly, what flowers are attractive for these natural enemies and provide suitable food. Moreover, we try to avoid flowering plants that are potential weeds, or benefit pest species (Wäckers et al., this volume). Thirdly, we try to establish the optimal spacing and timing of floral resources, while we also address the issue of how margins should be managed to optimize benefits.

Of all field crops studied Brussels sprouts is the most complex in terms of pest control. This is due to the fact that *Brassica* species are attacked by a range of herbivore species (including several aphids, many caterpillars, root flies and thrips), combined with the extended growing season, and the high crop value. Growers therefore typically apply insecticides 5-8 times per season. Of all pests the cabbage aphids (*Brevicoryne brassicae*) are often the most damaging. Biological control of this species can be problematic as it is only attacked by a limited number of aphidophagous species. Lady beetles are rarely seen on this crop and among the generalist aphid parasitoids, this aphid is only parasitized by *Diaeretiella rapae*. In addition, it is attacked by a predaceous gall midge (*Aphidoletes aphidimyza*) and a range of aphidophagous hoverflies (syrphids). Whereas all these species have carnivorous larvae, the adult stages strictly feed on nectar and pollen. Among these species, syrphids are most dependent on floral resources as they require both sugars and pollen in order to produce eggs (Haslett, 1989). Here we investigate the impact of floral resources on syrphid fitness parameters and the impact on biological control.

Lab experiments

To investigate the role of floral resources in the life history of syrphids and in their interaction with cabbage aphids, we conducted a series of experiments in 130 dm^2 gauze cages placed in illuminated climate chambers. As source of floral nectar and pollen we used plants of buckwheat, *Fagopyrum esculentum*. The flowers of these plants are known to be beneficial for several natural enemies (Winkler et al., 2006). Each cage was provided with two small Brussels sprouts plants infested with cabbage aphids, which are used by the female syrphids to oviposit her eggs. We focused on one common aphidophagous syrphid species, *Episyrphus balteatus*. For each experiment fresh pupae from this species were obtained from Koppert B.V. (Berkel and Rodenrijs). Each cage was provided with one newly emerged (<24 hour) female, as well as one or two newly emerged males.

Impact of aphid honeydew and flowers on syrphid survival and reproduction

The impact of aphid honeydew on syrphid survival was studied by varying the level of aphid infestation at the start of the experiment. As a positive control we provided a (1 molar) sucrose solution. The impact of buckwheat flowers was studied under high honeydew levels only, as honeydew is an important trigger for oviposition (Bargen et al., 1998). In addition, we varied the time frame at which the flowers were present: the first 6 days or the full period.

Table 1. Adult survival and female reproduction of *E. balteatus* under different food conditions (22°C, 80% RH).

Treatment	N (cages)	Mean longevity (days)	% females reproducing
Low honeydew (1 day before, 50 aphids/plant)	8	2.3	0
High honeydew (3 days before, 250 aphids/plant)	6	9.4	0
Low honeydew + sucrose solution (1 molar)	10	15.0	0
High honeydew + buckwheat (1st week only)	10	18.7	60
High honeydew + buckwheat (permanent)	22	21.3	55

Table 1 shows that E. *balteatus* can benefit from a high honeydew level, as this increases its longevity four-fold compared to the low honeydew situation. In the presence of sucrose the longevity increases further. This indicates that honeydew of cabbage aphids is suboptimal as sugar source. The provision of buckwheat, which provides both nectar and pollen, results in a further longevity increase. When the syrphids have these flowers available during their pre-oviposition period only, their longevity was not significantly reduced. This indicates that these syrphids can store their food reserves for several days.

Reproduction clearly occurs only when pollen is available. However, even when buckwheat flowers are permanently present, 45% of the females in the experiment do not produce any eggs. Possibly these females have not mated successfully, or miss the ability or right trigger to oviposit. When flowers are available during the pre-ovipositional period only, the fraction of females that reproduce is not lower, nor the number of eggs produced in the first week of reproduction. In the following two weeks, however, almost no eggs are produced by these females anymore, whereas with flowers oviposition continues, albeit at a lower rate than before. These results suggest that female syrphids can focus on flower foraging during the first week after emergence, and thereafter on foraging for oviposition sites (in the crop). Later, the syrphid will have to travel between floral patches and aphid patches.

Impact of syrphids on cabbage aphid dynamics

To investigate the potential impact of syrphids on cabbage aphids when provided with floral resources, we studied the population dynamics of cabbage aphids on Brussels sprout plants (initially 7 week old, 8 leaves per plant, 2 plants per cage) in cages with or without buckwheat plants. One day before the newly emerged female and male syrphids were put in the cage the number of aphids on the sprouts plants were adjusted to c. 30 per plant.

The results show that in absence of reproducing syrphids the aphid colony growths to 4000 aphids in 3 weeks. In presence of a reproducing female the number of aphids remains low during 3 weeks, resulting in a 7-fold lower aphid population compared with the control. The conclusion is that in the presence of (buckwheat) flowers the offspring of one female syrphid can suppress the growth of an aphid colony during several weeks.

Field experiments

In two successive years field experiments have been conducted at two small non-commercial Brussels sprouts fields of 100 by 24 or 14 meters. At the long western edge of the fields a strip was sown with annual plants. One part was sown with a mixture of flowers that can provide nectar and pollen for different natural enemies (buckwheat, cornflower and borage provided the main flowers from week 25 till week 40). Another part was sown with *Vicia faba* (broad bean or field bean). This species has extrafloral nectaries that are used by parasitoids and predatory beetles, and is functional from week 25 till week 32. The first year the two strips were separated by a strip of short grass, which served as a control.

Syrphid response to flowering field margins

In both years the highest numbers of syrphids were recorded in the second half of July (c. week 29, Figure 1). During September the numbers dropped to virtually zero. In both years the mixed flowers (and especially buckwheat and cornflower) attracted much more syrphids than *Vicia faba*. In the mown grass strip almost no syrphids were recorded. *Epysyrphus balteatus* made up about 45% of all syrphids in both years.

Syrphid and cabbage aphid dynamics in the crop

In the crop the number of eggs and larvae of syrphids peaked in week 31 (2005), one week later than the adult syrphids in the flower strip. Thereafter the numbers rapidly declined and were virtually absent beyond mid September. During the whole summer period nearly twice as many syrphid offspring were found in the section adjacent (<4 meter) to the mixed flower strip compared to the other sections. This indicates that syrphids are stimulated by the presence of these flowers.

The difference in syrphid density between field sections did not result in significant different aphid densities (in either year). Possibly, natural enemies less dependent on floral resources, such as parasitoids, compensated for the small scale differences in syrphid density.

On the insecticide-free sprout plants the mean number of cabbage aphids per plant remained below 15 until mid August 2004. After week 34, however, the population expanded rapidly, to exceed 300 aphids in week 40. In 2005, the density of cabbage aphids was higher from the start, but again remained stable throughout the summer period (at c. 40 aphids). After week 35 aphid number started to increase again. The resurgence of the cabbage aphids in autumn when natural enemies, such as syrphids, virtually disappear, suggests that these natural enemies play an important role in keeping the aphids under control during summer.

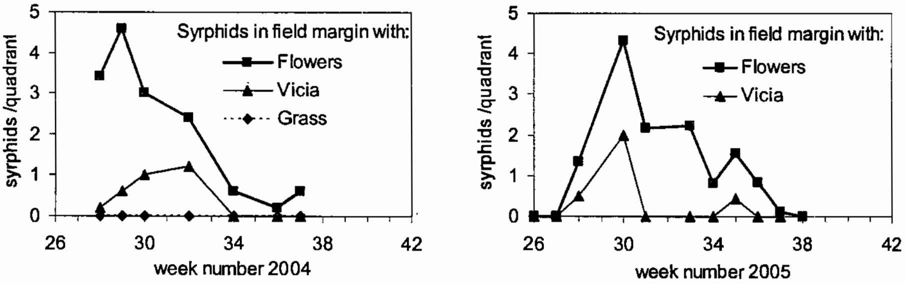

Figure 1. Mean number of aphidophagous syrphids per quadrant ($3m^2$) for different field margins in 2004 and 2005.

Acknowledgements

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The damage pattern of *Helicoverpa armigera* and *Ostrinia nubilialis* on maize in relation to landscape attributes - comparing two databases of Hungary at country level

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Abstract: A simulation approach was developed to investigate if territorial differences in the damage caused by *H. armigera* and *O. nubilialis* on maize could be explained by the differences in the landscape structure by using two available, independent national databases. Higher agricultural utilization rate for and the increase of the patch size correlated to a higher rate of infestation. On the other hand a higher rate of compensation areas and the increase of the fragmentation (relative edge density and shape index) correlated to a lower rate of the damages at landscape level. We suggest synthesizing the databases developed by different organizations for the analysis of ecological interactions at landscape level.

Keywords: *Helicoverpa armigera, Ostrinia nubilialis*, landscape structure, CORINE, database

Introduction

According to recent studies there exist different approaches to investigate the effect of the landscape structure on the agrobiont species. It is possible to use a pest species as an indicator organism and estimate its population and its caused damage at field scale in accordance with surrounding landscape characters (Den Belder et al., 2003). The pest species and its spatial distribution can be observed directly in one region with mark-and-capture technology (Fitt et al., 1995). Bukovinszky et al. (2003) observed three pest species on the same crop in one given region and found different responses of the three species to the landscape. Selected parameters of foraging behavior that are likely to be different among the observed species were studied. Feier et al. (2003) estimated the population of pests and their antagonists in wheat fields in two different landscapes (one moderately fertile and well-structured, the other fertile and less structured). In another approach the direct effect of the natural enemies influenced by the landscape structure can be estimated independently from pests and their damages (Bianchi et al., 2005).

We developed a simulation approach to investigate if territorial differences in the rate of damage caused by *H. armigera* and *O. nubilialis* on maize could be explained by the differences in the landscape structure by using two available, independent national databases, which were originally developed for different purposes.

Material and Methods

For the evaluation of the damage in 2003 and in 2004 the official database of the National Plant Protection and Soil Conservation Service (NTKSZ) were used. Hungary is divided to 141 plant protection zones where the damages of the most important pests are evaluated yearly. In the case of these two pests (*H. armigera, O. nubilialis*) the maize fields were classified in 5 damage classes and the values are given in percentage of the sown area, evaluated two times a year. Our calculations were done with this 3 contracted categories (D0=non infested area; D1+D2=less infested area; D3+D4=high infested area).

For the description of the landscape structure GIS ArcView 3.1 was used. Based on scale 1:50000 land cover / land use map CORINE Land Cover 50 (CLC50; Büttner et al., 2004) five variables were calculated in each plant protection zones (relative edge density, shape index, rate of compensation area, agricultural utilization rate, average patch size).

Results & Discussion

The damage of *H. armigera* correlated significantly (Table 1) to the landscape variables (Fig. 2) in 2003, which was a year of invasion (in 2003 there are no data on *O. nubilialis*, because it appeared in negligible quantity, in 2004 *O. nubilialis* invasion, but less *H. armigera*). In the year of the invasion (2004) *O. nubilialis* showed no significant correlation (Table 2) to all of the landscape variables.

The territorial differences of the damage cannot be explained by proportion of the maize fields (no significant correlation, df>100, d=0.05), although *H. armigera* colonizes crops within 10 km of their emergence site, and despite the crop species have the biggest influence on the destination of the *Helicoverpa* individuals (Fitt et al., 1995). This result is in contrast with the viewpoint that the lower proportion of susceptible crops in rotations reduces the crop to crop infection (Booij, 2003) at landscape level. On the other hand a higher utilization rate for agriculture resulted in a higher rate of infection at landscape level (according to recent studies Beckler et al., 2004; Den Belder et al., 2003; Klug et al., 2003), probably because of the polyphagia (eventually higher proportion of sunflower fields), or because of the lower rate of the compensation area. The effect of land use patch size depends on the foraging behavior of the species (Bukovinszky et al., 2003). We found a higher rate of infection in larger patch sizes. Similar phenomena were described in case of some other mobile species such as *Pieris rapae* (Bukovinszky et al., 2003) or *Diabrotica virgifera virgifera* (Beckler et al., 2004).

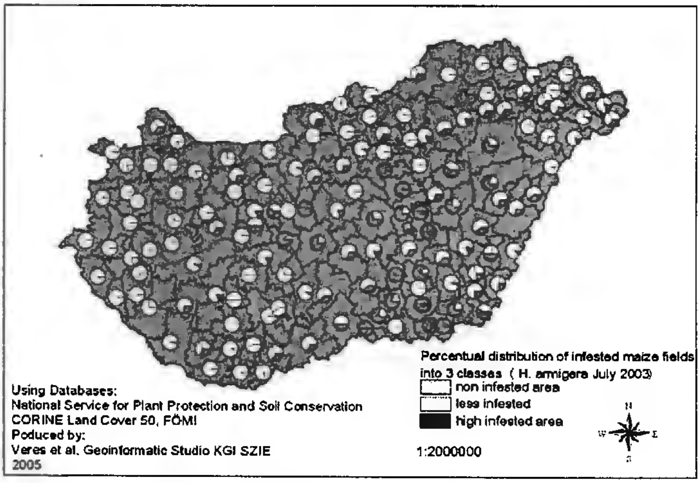

Figure 1. The percental distribution of the maize fields divided into 3 classes in the plant protection regions based on the damage of *H. armigera* in 2003 in Hungary.

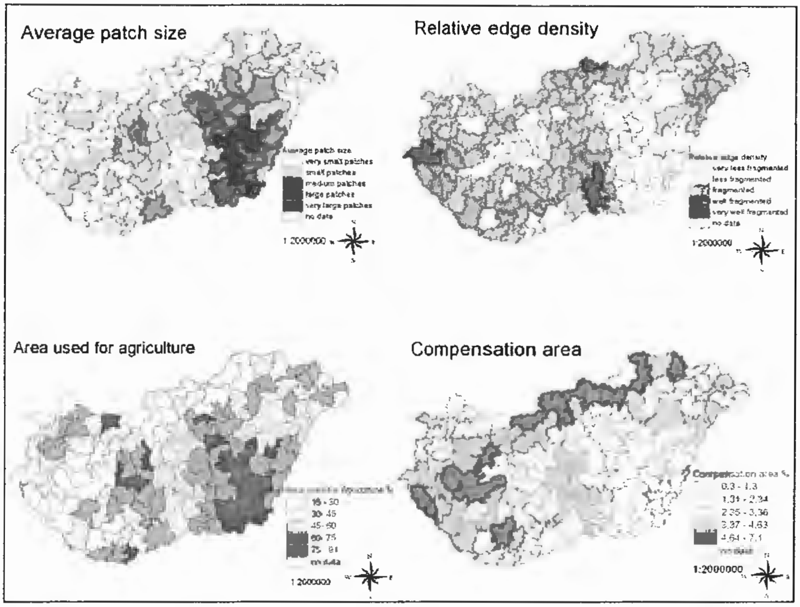

Figure 2. Variables of the landscape structure calculated with CLC50 (Büttner et al., 2004).

Table 1. Correlation between the variables of the landscape structure calculated and the percentage distribution of the maize fields based on the damage of *H. armigera* in 2003.

	No damage (DO)		Less damage (D1+D2)		More damage (D3+D4)	
	July	August	July	August	July	August
Rate of compensation area	**0.239** **p<0,02**				**-0.383** **p<0,01**	**-0.254** **p<0,01**
Relative edge density	**0.314** **p<0,01**				**-0.280** **p<0,01**	
Shape index	**0.353** **p<0,01**	**0.379** **p<0,01**			**-0.288** **p<0,01**	**-0.244** **p<0,02**
Average patch size	**-0.3531** **p<0,01**	**-0.218** **p<0,05**			**0.434** **p<0,01**	**0.282** **p<0,01**
Utilization-rate for agriculture	**-0.235** **p<0,02**				**0.399** **p<0,01**	**0.280** **p<0,01**

Table 2. Correlation between the variables of the landscape structure and the percentage distribution of the maize fields based on the damage of *H. armigera* and *O. nubilialis* in 2004.

	No damage (D0				Less damage (D1+D2)				More damage (D3+D4)			
	July		August	Sept.	July	August	Sept.	July	July	August	Sept.	July
	H.a	***O.n***	***H.a***	***O.n***	***H.a***	***O.n***	***H.a***	***O.n***	***H.a***	***O.n***	***H.a***	***O.n***
Rate of compensation area					**-0.221** **p<0,05**	**-0.205** **P<0,05**						
Relative edge density												
Shape index			**0.248** **p<0,02**			**-0.264** **P<0,01**		**-0.214** **p<0,05**				
Average patch size									**0.249** **p<0,02**			
Utilization-rate for agriculture					**0.217** **p<0,05**							

On the other hand in our study the rate of compensation areas negatively correlates to the rate of the damages, which can be explained by the spatial isolation of crop fields (Booij, 2003), by the enhanced diversity of the natural enemies (Bianchi et al., 2005) and also by the foraging behavior of the pest species (Bukovinszky et al., 2003, Fitt et al., 1995). These results are in contrast with the experiments on *Autographa gamma,* where the extent of damage and the population density did not depend on the presence of natural habitats (Klug et al., 2003). Also the variables of relative edge density and shape index negatively correlate with the rate of damages, so the landscape pattern seems to influence the damage of *H. armigera* at large scale in the year of invasion (Fig. 1, Fig. 2).

In conclusion by using of available national databases we could analyze the effect of the landscape structure on two pest species. We suggest synthesizing and the wider use of the databases for the analysis of ecological interactions at landscape level.

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Poster

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The egg parasitoids of the genus *Anagrus* (Hymenoptera: Mymaridae) as functional biodiversity of the vineyard agroecosystem

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Abstract: *Anagrus* spp. (Hymenoptera: Mymaridae) are important egg parasitoids of leafhoppers (Homoptera: Cicadellidae) and well-suited biocontrol agents, but they are still poorly known.

In a long term study started in 2002, and still going on in some southern regions of Italy (Basilicata and Campania), the *Anagrus* complex presents in vineyards and surroundings was studied by using sticky yelow traps and samples of leaves with parasitized leafhopper eggs picked up on several plants.

All specimens of *Anagrus* collected, with a very few exceptions, were identified *Anagrus* group *atomus* (Linnaeus). Their populations showed two forms, at present considered distinct species and named *A. atomus* (Linnaeus) and *A. ustulatus* Haliday. This complex resulted widespread and reproducing all year around. Several plants (*Rubus ulmifolius*, *Quercus ilex*, *Lonicera implexa*) are important sources of *Anagrus* during late winter and spring.

Keywords: *Anagrus*, vineyard, leafhopper

Introduction

The species of the genus *Anagrus* (Mymaridae) (Figs. 1-4) are important egg parasitoids of leaf hopper, but only in the last decades they were rather intensively investigated. Most of the species are very poorly known and their identification still remains questionable.

In order to clarify the structure of the *Anagrus* populations present in the vineyard agroecosystem and their biocoenotic relationship, a long term study started in 2002 and is still going on in some southern regions of Italy (Basilicata and Campania). Preliminary results are given in the present paper.

Fig. 1. *Anagrus ustulatus* Haliday, female

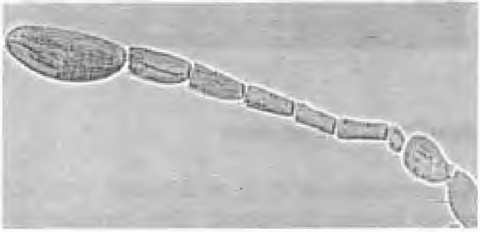

Fig. 2. *Anagrus ustulatus*, female: antenna

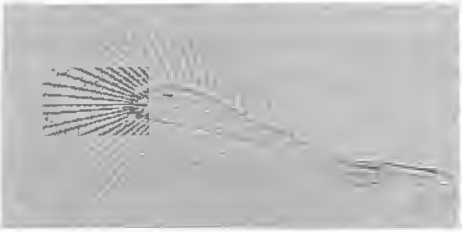

Fig. 3. *Anagrus ustulatus*, female: fore wing

Fig. 4. Leafhopper egg parasitized by *Anagrus*

Material and Methods

Yellow sticky traps (Fig. 5) were placed in vineyards and surroundings to collect *Anagrus* spp. Samples of this material was taken off from the sticky traps and used to make slides for specific identification. Meanwhile, samples of leaves and branches of several plants (weeds, bushes and trees) were picked up. More intensively were sampled the following plants: *Acanthus mollis*, *Conyza naudinii*, *Ficus carica*, *Geranium* sp., *Lonicera* spp., *Mentha* sp., *Myrtus communis*, *Phytolacca decandra*, *Qercus ilex*, *Q. pubescens*, *Rubus ulmifolius*, *Salix* sp., *Scrophularia peregrina*, *Silene* sp., *Solanum tuberosum*, *Sorbus* sp., *Ulmus minor*, *Urtica dioica*, *Vitis vinifera*.

On each sample all leafhopper parasitized eggs containing full larvae or pupae of *Anagrus* were singly isolated and mantained in microcapsules. The emerged adults were mounted on slides and identified.

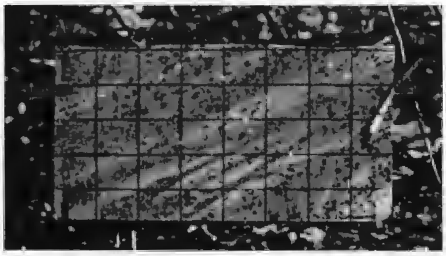

Fig. 5. Yellow sticky trap on bramble hedge.

Results and Discussion

All specimens of *Anagrus* collected, with a very few exceptions, were identified *Anagrus* group *atomus* (Linnaeus). Their populations showed two forms (Figs. 6-8), at present considered distinct species and named *A. atomus* (Linnaeus) and *A. ustulatus* Haliday (Chiappini et al., 1996). On some hosts only *A. atomus* was present, whereas on others *A. ustulatus* or both were recorded.

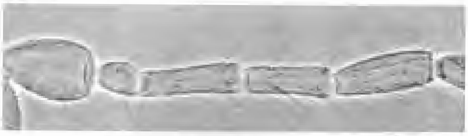

Fig. 6. *Anagrus atomus*, female: IV funicular segment of antenna with a linear sensillum.

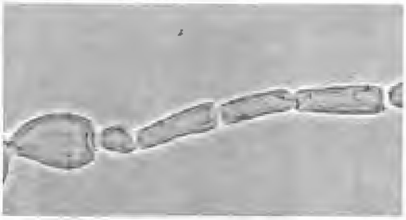

Fig. 7. *Anagrus ustulatus*, female: IV funicular segment without linear sensillum.

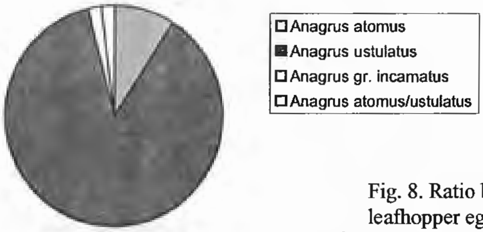

Fig. 8. Ratio between *Anagrus* species obtained from leafhopper eggs on bramble in 2003.

On the leafhopper hosts (Fig. 9-10) on *Rubus ulmifolius* and *Vitis vinifera* were previously reported (Viggiani et al., 2004a, 2004b). This complex resulted widespread and reproducing all year around. In fact, it was observed that under the climatic conditions of the experimental area, *Anagrus* populations can overwinter both as adult and as uneven young stages. Adult emergence was recorded since late February. Several plants (*Rubus ulmifolius*, *Quercus ilex*, *Lonicera implexa*) are important sources of *Anagrus* during late winter and spring. They may be managed to increase the density of these egg parasitoids in vineyards early in growing season.

The *Anagrus* complex reproducing in the different wine-growing regions seems rather diverse as was observed in the Franconian vineyards of Germany (Boell & Hermann, 2004) and this needs to be taken into account for a rational biodiversity management.

Fig. 9. *Ribautiana cruciata* (Ribaut), leafhopper very common on bramble

Fig. 10. *Hauptidia provincialis* (Ribaut), a widespread leafhopper on many weeds

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Flower power? Potential benefits and pitfalls of using (flowering) vegetation for conservation biological control

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Abstract: Whereas nectar and pollen provision to predators and parasitoids is a main objective in pursuing agricultural biodiversity, we often know little about whether the flowering plant species involved are actually suitable as insect food sources or about their ultimate impact on biological pest control. Here we highlight the potential as well as the pitfalls of using biodiversity in conservation biological control, and discuss how we can optimize the benefits.

Key words: nectar, extrafloral nectar, pollen, flowers, honeydew, predator, parasitoid, conservation biological control, functional biodiversity, companion planting

Introduction

Non-crop vegetation in the agricultural landscape can provide a range of ecological services. Besides offering a suitable habitat and food for birds and other types of wildlife (Marshall & Moonen, 2002), field margins or fallow areas may contribute to the conservation of native flora (le Coeur et al., 2002) and may reduce agrochemical runoff and drift (Marshall & Moonen, 2002) as well as prevent soil erosion (Pimentel & Kounang, 1998). In addition to these environmental benefits, field margins may also help enhance crop production by providing shelter and supplementary foods for beneficial arthropod species such as pollinators (Goulson, 2003) and predators or parasitoids (Gurr et al., 2005; Wilkinson & Landis, 2005).

Potential of a simple concept: using biodiversity to boost biological control

A broad range of biological control agents depends on flowering vegetation as a source of nectar and pollen (Wäckers & van Rijn, 2005). The scarcity of these food sources in modern agricultural systems can severely reduce the longevity and the reproductive success of parasitoids and predators and thus compromise the effectiveness of biological pest control. Winkler et al. (2006) showed that the majority of *Diadegma semiclausum* failed to attack any *Plutella xylostella* larvae in semi-field cages lacking nectar plants, whereas individuals provided with a nectar plant parasitized more than 300 larvae each.

Recent studies indicate that natural enemies can indeed be food-deprived in the absence of flowering vegetation (Wäckers & Steppuhn, 2003). Thus, adding food sources to agro-ecosystems could be a simple and effective way to enhance the effectiveness of biological control programs. Using HPLC to determine sugar reserves in field collected parasitoids, we demonstrated that parasitoids collected in a cabbage field bordered by a flowering field margin showed higher levels of sugar reserves than those collected from a conventional cabbage field. The specific sugar composition showed that 80% of parasitoids had been feeding and that both floral nectar and honeydew had been consumed (Wäckers & Steppuhn, 2003). Together with a parallel study (Lee & Heimpel, 2003), this work shows that biological control agents under field conditions actually obtain an energetic benefit from flowering field margins.

Why it is not quite so simple. Misconceptions and potential pitfalls

Biodiversity inherently benefits biological control

It is often thought that increasing botanical diversity in itself enhances biological pest control (see (Tscharntke et al., 2005) for an excellent review). While such a generalization might be appealing, it does not address or elucidate the underlying mechanisms. From a scientific standpoint such a 'black-box approach' is obviously unsatisfactory. But also from an applied standpoint it proves to have severe limitations, as the lack of insight in the mechanisms underlying success or failure makes it difficult to actually build on 'hits' and avoid the 'misses'.

In a comprehensive review Andow (1991) shows that an increase in diversity does not necessarily result in reduced herbivore levels. It could be argued that the correlation between vegetational diversity and nectar availability might be more straightforward. However, in a recent study (Olson & Wäckers (submitted)) we show that diverse naturally regenerated edge vegetation used for functions other than conservation biological control (quail set-asides) does not provide any nutritional benefit to parasitoids in adjacent cotton fields. HPLC analysis of gut contents showed that the sugar reserves in these parasitoids did not exceed levels in unfed controls, and that the majority of collected individuals were on the brink of starvation. In sharp contrast, sugar levels in parasitoids collected along a field margin exclusively containing the vetch *Vicia sativa* x *Vicia cordata* showed an average sugar level that was more than three times the average levels in fields bordered by quail set-asides. This strongly suggests that the high vegetational diversity in regenerated edges contributed little or nothing to parasitoid nutrition, whereas the low diversity vetch margin had a dramatic impact. This not only challenges the concept that high vegetational diversity per se is benefiting biological control, it also underlines that conservation biological control can be optimized through the provision of specifically selected food plants (Baggen et al., 1999; Wäckers et al., 1996).

It's in the nature of flowering plants that they provide suitable nectar and/or pollen

It is often implicitly assumed that the presence of flowers warrants the presence of suitable nectar and pollen. This assumption ignores the extensive variation among flowering plants with regard to their apparency, accessibility, and nectar/pollen composition, as well as the often harsh competition for these food sources (Wäckers, 2005). Each of these factors can be a serious obstacle to successful feeding by predators or parasitoids. Not all flowers are attractive to flower foraging insects (Wäckers, 2004). Once a flower has been located, the insect might not be able to access the floral food (Baggen et al., 1999; Wäckers et al., 1996), or the chemical composition of the nectar/pollen might render it nutritionally unsuitable (Wäckers, 2005). By selecting those foods whose availability, appearance, accessibility and chemical composition matches the behavior, morphology and physiology of target organisms, we can optimize the benefits to biological control.

Other trophic levels may also benefit from flowering plants

When introducing flowering non-crop elements to the system, there might be a further snake in the grass. The adult stage of many herbivores are dedicated and effective flower feeders as well (Romeis et al., 2005). Winkler et al. (in prep.) observed significantly higher numbers of the small cabbage white (*Pieris rapae*), as well as an increased number of their eggs and caterpillars in Brussels sprout plots bordered by *Centaurea jacea* compared to control plots.

In a separate study (Winkler et al. in prep), we were able to show that herbivores in cabbage adjacent to a flowering margin show significantly elevated sugar levels relative to individuals in control fields.

Apart from herbivores and their natural enemies, also higher trophic levels such as hyperparasitoids, may use and profit from the introduced flowers (Jervis et al., 1993). Biological control efficacy can be strongly hampered by the occurrence of hyperparasitoids (Holler et al., 1993). It is yet unknown how floral resources affect the balance between primary parasitoids and hyperparasitoids (Gurr et al., 2005). By identifying and exploiting differences in foraging behavior and food use between herbivores, their enemies and higher trophic levels, negative effects of food provision may be avoided (Baggen et al., 1999; Wäckers, 1999, 2005; Winkler et al., 2005).

Conclusions

- Flowering vegetation can be a powerful tool to enhance survival and reproductive success of predators and parasitoids of agricultural pests, tipping the balance towards success of biological control programs.
- Biodiversity in itself is not a guarantee for the enhancement of biological control. Non-crop structures designed for other ecological functions may be unsuitable for conservation biological control.
- It is important to gain insight in how non-crop elements affect the ecology of all species relevant to crop production, including herbivores and hyperparasitoids.
- Arbitrarily chosen nectar and pollen sources may be counterproductive when they are primarily exploited by pests.
- Benefits of biodiversity to biological control programs can be optimized by selecting flowering species that provide vital resources for predators or parasitoids, without providing benefits to herbivores.
- We momentarily apply and study this 'selective approach' in two large scale field projects on functional agro-biodiversity in the Netherlands: one near Heteren in orchard systems, and one in the Hoeksche Waard focusing on horticultural and arable crops (Van Alebeek, this volume)

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Strategic use of nectar sources to boost biological control

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Abstract: Introducing nectar sources to an agricultural cropping system is one option to enhance the availability of nectar for beneficial insects. As pest insects may benefit from nectar sources as well, flowering vegetation might unintentionally increase pest pressure. We identified two groups of selective plant species that either promoted the pest species or their natural enemies. By planting field margins with species from either group we subsequently studied the potential benefits as well as the risk of implementing nectar plants in agricultural settings.
In experimental tents large enough to allow natural behaviour we could demonstrate the great importance of a suitable nectar plant for parasitoid survival and fecundity. In the open field, we could show for the first time that nectar plants enhance the nutritional state of an herbivore under field conditions. We demonstrate that choosing the wrong type of flowers can actually enhance pest pressure in agricultural systems. We conclude that a selective approach and a careful choice of plant species are necessary to achieve improved biological control by flowering field edges.

Key words: nectar, cabbage, *Pieris rapae, Plutella xylostella, Diadegma semiclausum*, parasitoid, selective food plants

Introduction

The establishment of flowering field margins is one option to provide nectar for beneficial insects in agro-ecosystems. Many researchers have demonstrated the importance of nectar sources for survival and reproduction of beneficial insects like parasitic wasps (Leius, 1960; Syme, 1975; Wäckers, 2001; Wäckers and Steppuhn, 2003). However, in addition to possible positive effects on predators and parasitoids, introducing nectar sources to an agricultural cropping system could also have negative impacts when pest insects benefit from these same food sources (Baggen et al., 1999; Romeis and Wäckers, 2002; Zhao et al., 1992).

In a previous study we investigated whether two important lepidopteran pests of cabbage, *Pieris rapae* L. and *Plutella xylostella* L., and their hymenopteran parasitoids, *Cotesia glomerata* L. and *Diadegma semiclausum* Hellén can obtain nutritional benefits from 19 flowering plants (Winkler et al., 2003). We aimed at the identification of 'selective' plants that mainly, if not exclusively, promote the performance of natural enemies. This study revealed that certain flowering plants show selectivity in the other direction, by primarily benefiting the pest species. The identification of these two groups of selective plants, subsequently allowed us to study best case and worst case scenarios by planting field margins with species from either group. This would represent the potential benefits as well as the risk of implementing nectar plants in agricultural settings.

Material and methods

Benefit assessment – semi-field

Under semi-field conditions with standardized host density and host distribution we tested the effect of a suitable nectar source on realized lifetime fecundity of the parasitoid *D. semiclausum*. In twelve tents, each 3m wide, 4m deep and 2m high, Brussels sprouts were planted in three rows. In six tents flowering *F. esculentum* was placed, the other six tents were considered as control.

At the start of the experiment, we released one newly emerged female together with one male in each of the tents. On each experimental day, we placed three cabbage leaves, invested with ten L2 *P. xylostella* each, in each of the tents. About seven hours later the infested leaves were recollected and taken into the laboratory. The caterpillars were dissected and checked for the presence of *D. semiclausum* eggs during the following day. For details see Winkler et al. (2006).

Risk-benefit assessment – open field

Under field conditions we monitored pest densities and parasitism rates in small Brussels sprout fields bordered by either "herbivore selective" or "parasitoid selective" nectar plants. Field margins contained one of the following plants: *Lolium perenne* (grass, control without nectar), *Centaurea jacea* (especially suitable for *P. rapae*), *Anethum graveolens* (especially suitable for parasitoids), or *Fagopyrum esculentum* (suitable for both).

Naturally occurring adult insects were monitored on sunny and dry days by either direct observation (*Pieris* sp) or sweep netting (*P. xylostella* and *D. semiclausum*) in the Brussels sprout fields. Brussels sprout plants were randomly monitored for *P. rapae* eggs and larvae and for *P. xylostella* larvae and (parasitized) pupae.

Nutritional state

We investigated the effect of different flowering plant species on the nutritional state of the parasitoid D. semiclausum and its host P. xylostella. Individuals were collected in Brussels sprouts fields bordered by flowering margins or grass as control like described above. In addition, Brussels sprouts fields bordered by Sweet Alyssum (Lobularia maritima) were included. Insects collected in these fields were analyzed by HPLC to establish overall sugar content as a measure of their energy reserves.

Results and discussion

Benefit assessment – semi field

In our benefit assessment we could confirm that feeding is of crucial importance to parasitoid survival and fecundity. Unlike most laboratory settings, our experimental tents were large enough to allow natural behaviour including long distance foraging and searching for hosts. In the control treatment nine out of eleven parasitoids failed to oviposit at all. This is in contrast to reports from laboratory studies, in which unfed parasitoids were able to parasitize nearly as many hosts as fed females on the first three days (Cardona, 1997; Yang et al., 1993). In the buckwheat treatment, wasps apparently successfully located and accessed the nectar source. Nectar availability increased the average reproductive lifespan of the parasitoids from 1.2 days (control) to 28 days. Females without access to nectar failed to parasitize at all or parasitized few larvae (3.7±4.4). Females with access to nectar parasitized an average of 390±31 larvae. For detailed results see Winkler et al. (2006).

Risk-benefit assessment – open field

In our field study we could demonstrate that the indiscriminate use of nectar plants in flowering field margins can enhance pest pressure. The herbivore *P. rapae* showed higher egg and larval densities in fields bordered by *C. jacea* and *F. esculentum*, two flower species that had been shown to be suitable nectar sources for this herbivore (Winkler, 2005). Moreover, adults of this species were recorded more frequently in fields bordered by *C. jacea*.

We did not see any significant impact of flower margins on *P. xylostella*. Even though all of the flowers tested extended *P. xylostella* longevity under laboratory conditions, neither adults nor caterpillars showed increased numbers in fields with flower margins, relative to the control. This is most probably due to the lower mobility of *P. xylostella* as compared to *P. rapae* (Bukovinszky et al., 2005; Justus and Mitchell, 1996).

We expected higher parasitoid numbers and, consequently, increased rates of parasitism in fields bordered by *A. graveolens* and *F. esculentum*. Laboratory, as well as semi-field experiments demonstrated the positive impact of *F. esculentum* and *A. graveolens* on the longevity of *D. semiclausum* (Winkler, 2005; Winkler et al., 2006) and *Diadegma insulare* (Lee et al., 2004), as well as a great impact of *F. esculentum* on fecundity of *D. semiclausum* (Wratten et al., 2003). Regardless of the treatment, we found high rates of parasitism by *D. semiclausum*: 65% in 2002 and 80% in 2003. The density of *P. xylostella* larvae did not differ among the treatments. The parasitoid might have exploited alternative food sources like honeydew, produced by the cabbage aphid *Brevicoryne brassicae* or by the cabbage whitefly *Aleyrodes proletella* (Wäckers and Steppuhn, 2003). In addition, high mobility of *D. semiclausum* might have caused a "treatment dilution effect".

Nutritional state

P. xylostella showed increased numbers of fed individuals and higher levels of total sugar content in Brussels sprout fields bordered by *A. graveolens* and *L. maritima*. The two other flower species, *C. jacea* and *F. esculentum*, did not alter the nutritional state of *P. xylostella*. In three out of the four treatments individuals were shown to contain melezitose, indicating consumption of honeydew by the herbivore (Heimpel et al., 2004).

For *D. semiclausum*, the far majority of collected individuals in all five treatments had consumed sugars. Whereas the values of total sugar content were highest in the flower treatments, sugar levels did not differ significantly from the control. None of the flower species that provide accessible nectar under laboratory conditions yielded raised sugar levels among parasitoids collected. For further details see Winkler (2005).

Conclusions

Exceeding previous findings from laboratory studies we demonstrate that food is even more important for parasitoid survival and fecundity under natural conditions where insects have to fly in order to find food and hosts. In addition, we could show for the first time that nectar plants enhance the nutritional state of an herbivore under field conditions and demonstrate that choosing the wrong type of flowers can actually enhance pest pressure in agricultural systems. This kind of detailed knowledge helps us to understand at least part of the complex processes taking place in diverse agro-ecosystems and might allow us to manipulate diversity to our benefit.

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