The effect of landscape composition on pests and natural enemies, with reference to the minute pirate bug abundance (*Orius* spp.)

PhD thesis

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1 INTRODUCTION

Concerns over the impact of pesticides on the environment and human health call for alternative pest control methods. Among these, the manipulation of the landscape and habitat structures has been suggested as a means to influence the dynamics of both insect pests and their natural enemies. Pest outbreaks and pest control by natural enemies indeed have strong links to landscape patterns and do not depend only on local in-field conditions.

Up-scaling from field to landscape appears necessary because most pests and natural enemies need to move over the landscape to search for resources: either they use various resources during their life-cycle (e.g. aphids that change hosts) or their resources are short lived (e.g. flowering crops). Contrarily to other landscape types, agricultural landscapes are indeed very dynamic and while semi-natural landscape elements such as woodlots or hedgerows are rather stable in time, most crops are subject to a high frequency of disturbance caused either by soil and pest management, changes in crop phenology, harvest or crop rotation that makes them periodically unsuitable (Bianchi et al. 2006). The impact of landscape features on pest abundance and pest control by natural enemies is thus expected to change within year and between years. This dynamic, however, is rarely considered and agricultural landscapes are generally characterized by their composition, i.e. the proportions of different land-cover categories, and their configuration, i.e. a synthetic description of their land use/cover spatial distribution.

Recognizing the need for up-scaling, a number of authors have reported relationships between some landscape characteristics (e.g. proportion of semi-natural area or proportion of area grown with a particular crop) and pest abundance or pest control. In the following, we will analyze what sort of relationships can be expected and what relationships are found in the literature. In general, because crops are habitats of pests, a positive relationship is expected between in-field pest abundance and the acreage of cultivated land at a landscape scale, in particular when considering a specialist pest and the particular crop it attacks. However, there are reasons for which this relationship could be flat or negative. First, some pests have alternative hosts and may spend an important part of their life cycle outside the crops (e.g. *16* Ostman et al. 2001, 19 Thies et al. 2005). Second, pests are generally fought against in crops where they could be the most abundant (e.g.*17* Ricci et al. 2009). Their abundance in fields may thus largely depend on the presence of small isolated non treated elements in the landscape (e.g. garden trees or vegetables, feral plants in field margin). Third, pest abundance may be reduced in landscapes providing more semi-natural areas because mortality caused by natural enemies may be higher. It has indeed been shown that the biodiversity and/or the abundance of pests' natural enemies in fields largely depend on the amount of non-crop habitats at landscape scale (Bianchi et al. 2006, Tscharntke et al. 2007, Attwood et al. 2008). This enhancement of biodiversity in crops provides no guarantee for effective pest control, but there is a tendency for more diverse pest enemy communities to better control herbivorous arthropods. In the first chapter, the results from a literature review are presentedon the impact that landscape composition has on the abundance of arthropod pests and on CBC effectiveness, measured in terms of parasitism or predation rates. We question separately the impact of landscape composition on pest abundance and on CBC because we did not find enough articles dealing both with CBC effectiveness and pest abundance. Our main three hypotheses are (i) that an increasing proportion of a given crop over the landscape correlates positively with its pest abundance. Further, because of the effect of semi-natural areas on biodiversity, we hypothesized that an increased area of semi-natural habitats (ii) leads to increased predation or parasitism and (iii) to a decreased pest abundance.

In the second chapter, the conclusions from the literature review are experimentally investigated. The experiment was carried out to develop IPM strategies for greenhouse sweet pepper production in the Jászság region. Predators of the genus *Orius* are produced by commercial insectaries and widely released to control western flower thrips, *Frankliniella occidentalis*, a serious pest in greenhouse sweet pepper production in Hungary. However, *Orius* species can colonize greenhouses spontaneously (Bán et al. 2009, Bosco et al. 2008) and their conservation biological control potential might depend on their abundance in the surroundings. Up-scaling from field to landscape is thus necessary. Identification of the resources habitats, their interaction with the landscape and bottlenecks in their lifecycle is the first prerequisite to build decision support systems.

Orius populations are most abundant on flowering plants, where they feed on arthropods and floral resources (Péricart 1972, Rácz 1989). They might move actively in the landscape following the changes of the resource patterns, because they search actively for prey-hotspots and leave plants of low prey density (Montserrat et al. 2004).Indeed wild *Orius* individuals contrarily to laboratory reared ones, respond to odours of thrips-infected plants (Carvalho et al. 2011). In Jászság region, *Orius niger* was found as the most abundant species both in greenhouses and in their surroundings (Bán et al. 2009, *23*Veres et al. 2008, Veres et al. 2010). *O. niger* is known to feed on western flower thrips, and prefers thrips than mites. Females do not search for habitat patches to oviposit, but are likely to lay eggs in patches where they are feeding in (Lundgren et al. 2009). However, they select the plants of the thinnest external tissues in the patch to bestow the greatest fitness for developing offspring, which are feeding only on plant nutrients at early stages (Lundgren et al. 2008). As such *Orius* was shown to be more abundant in vegetationaly diverse cropland than in fields without weeds due to higher survival probabilities on non-crop plants. Winter is a critical period for the *Orius* population. Only fertilized females enter diapause finding shelters under fallen leaves, in litter, under tree bark or in plant stems, so they overwinter with higher probability in semi-natural habitat. The quantity of food resources and the seasonal differences are important bottlenecks in their life cycle, thus the fecundity,the number of generations per season and the duration of larval development depends on the temperature (Rácz 1989, Saulich and Musolin 2009). In the second chapter, the abundance pattern of *Orius* adults and their relationship to typical habitats of agricultural landscape was analyzed in order to evaluate the *Orius* adults provided potentially by the landscape for conservation biological control in greenhouse sweet pepper production. Our main two hypotheses are first that *Orius* abundance pattern is aggregated in the landscape and second that this aggregation can be explained by their relation to semi-natural habitat.

2 STUDIES

2.1 DOES LANDSCAPE COMPOSITION AFFECT PEST ABUNDANCE AND THEIR CONTROL BY NATURAL ENEMIES? A REVIEW.

2.1.1 MATERIAL AND METHODS

2.1.1.1 Literature search

Our hypotheses are based on specific relationship between landscape feature surface and population size, therefore we decided to build a database and preform a meta-analysis. We searched for scientific articles in the Web of Science using keywords: landscape, agri* and one scientific name of arthropod taxa (based upon Attwood et al. 2008) and extended our search to articles citing those that we had found. We also contacted colleagues of the ENDURE network (http://www.endure-network.eu/) for information on studies that would not be in our list. We restricted our search to years 1993-2008. We selected studies that analyzed how (i) the abundance of a pest, (ii) the rate of a pest parasitism or (iii) the rate of a pest predation within a field depended on the proportion of cultivated area or of some semi-natural element at landscape scale defined as within a distance of at least 100m from the sampled unit.

2.1.1.2 Data collection

The basic units in the data base were named cases. They corresponded to one relationship between the abundance of an insect pest, its parasitism or predation and the area of one landscape feature. There were generally one to three cases per published study. In particular, we treated different pest taxa within a single study as independent cases. In case of multiple time periods, we used results from only one period, choosing the period for which the correlation had the lowest P-value. It is indeed likely that correlations between pest abundance, predation or parasitism and landscape composition will change within and between years and collecting the result with the lowest P-value allowed both collecting all observed landscape effects and avoiding to put disproportionately more weight on studies with multiple time sampling. In some articles the analysis was carried out at different scales, landscape composition being considered at different distances from the focal field. As it is likely that landscape effects, if present, cannot be detected at all scales but only at some scales that are relevant given the organism biology, we kept the results of the scale where the correlation between the studied variable and landscape composition took its highest value. If, for a given taxon, both the effects of the crop area and of some semi-natural area were reported in a single study, we considered them as independent cases only if these two categories did not cover the whole territory, i.e. they were not complementary. When more than one article reported about what appeared to be a single case, we considered the article that provided the more detailed results.

We first recorded variables describing characteristics of cases. Variable *ABUND* took value 1 if the case reported on abundance and 0 if it was about conservation biological control. Landscape descriptions were very heterogeneous. First some studies considered cultivated areas as a whole and others detailed area of a particular crop. Second some studies only reported on the area of some semi-natural element. We thus created the variable *CULT* that took value 1 if the case reported on the effect of any cultivated area and 0 if it was about semi-natural element. For studies that corresponded to *CULT*=1, we created an additional variable *CROP* that took value 1 if the considered cultivated area was that of the particular crop host to the pest and 0 otherwise.We created two dependent variables. First, to assess which type of studies showed a significant landscape effect, we created a variable *LANDS* that took value “1” if there was a significant landscape effect, either positive or negative, and “0” otherwise. Second, we created the variable *SIGN* that could take three values, ‘+’, ‘-‘ or ‘0‘ depending on the direction of the effect of landscape metrics on the pest abundance or CBC. For homogeneity, we placed ourselves from the point of view of the pest and reported a value ‘+’ when an increasing proportion of the measured landscape feature resulted in a significant increase of the pest abundance or a less effective CBC. Conversely, we reported a value ‘-‘ when an increasing proportion of the measured landscape feature resulted in a decreasing abundance of the insects or increasing CBC. Finally, we reported value “0” when there was no significant effect. The threshold of significance was taken from the article with a minimum value of P=0.05. We located 24 studies published between the years 1993-2008. 15 studies reported about pest abundance, 5 studies about CBC and four about both. These studies corresponded to 72 independent cases: 52 about pest abundance and 20 about CBC, i.e. predation (5 cases) or parasitism (15 cases).

2.1.2 STATISTICAL ANALYSES

To assess which cases showed a landscape effect, we performed exact Fisher tests (package *stats* in R2.1.1, R development Core team, 2008) on 2 x 2 contingency tables with categories defined by variable *LANDS* and either variable *ABUND* or variable *CULT*. To investigate the direction of landscape effects, we only considered significant cases. We performed chi-square tests to assess if increasing the area of a particular landscape feature would affect the pest positively (excess of '+'), negatively (excess of '-') or not (H0: 1/1 ratio of '+' and '-'). We performed these tests separately for cases dealing with cultivated and semi-natural elements. Than we considered only cases with *CROP*=1 and also tested if there was a trend in the direction of effects using chi-square tests comparing the distribution of '+' and '–'to a 1/1 distribution. As expected counts were sometimes below 5, all Chi-square tests were performed using 1000 simulations of expected distributions (package *stats* in R2.1.1).

2.1.3 RESULTS AND DISCUSSION

More than half of cases reported significant landscape effect (65% for cases about CBC and 61% for cases about pest abundance). Studies investigating the impact of cultivated and semi-natural area had similar probabilities of reporting significant landscape effects (Fisher exact test P=0.33). The same was true for studies investigating pest abundance or CBC (Fisher exact test, P= 0.99).

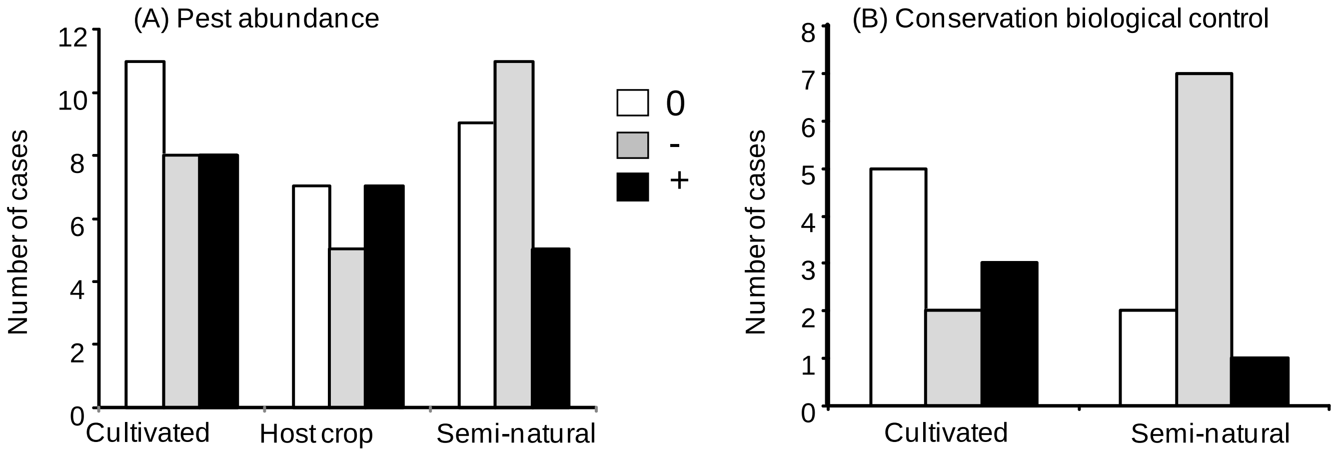

Figure 1.
Number of positive (more pest or less CBC), negative (less pest or more CBC) and non-significant cases concerning the impact of (A) increasing cultivated area, host crop area and semi-natural areas in the landscape on pest abundance and (B) of increasing cultivated and semi-natural areas on pest conservation biological control.

There were almost as many cases of positive (9) and negative (8) effects of increasing cultivated area on pest abundance (Table 1. P. 9.). There were only 5 cases reporting a significant correlation between cultivated area and CBC two of which indicating an increased CBC with increasing cultivated area (Table 2., P. 10.). Such low sample size obviously does not allow discriminating from a 1/1 ratio of '+' and '-'. As expected from the above results, no overall trend could be found on the direction of the relation between landscape scale amounts of cultivated area and levels of pest population and/or biocontrol (10 '-' versus 12 '+' cases, Figure 1., P.7.). Pest abundance showed contrasted responses to the area of the particular crop on which they were sampled (Table 3. P.11.). Out of the 18 cases, 12 were significant among which 7 showed increased pest abundance with increased host crop area (Chi^2=1.47, P=0.33).

There were a total of 10 cases relating amounts of semi-natural area and biocontrol (Table 4., P.12.) and 8 cases reported significant relations, of which 7 in the direction of enhanced CBC with increasing area of natural area (Chi^2=4.5, P=0.068) ('-' signs in Figure 1. 1B., 7.). There were 24 cases overall relating amounts of semi-natural area and pest abundance (Table 5., P. 13.) and 15 cases reported significant relations of which 11 were negative (Chi^2= 3.2, P=0.12) (Figure 1. 1A., 7.). A global analysis confirmed the suspected suppressive effect of landscape scale amounts of semi-natural areas on in-field pests. There was a significant excess of '-' signs (18'-' signs versus 5 '+' signs), i.e. either lower pest number or increased CBC with increasing semi-natural area (Chi^2=7.3 , P=0.01).

The analysis shows that the effect of increasing cultivated or host crop area on pest abundance were either positive or negative, with no clear trend. The positive effect of the proportion of semi-natural areas on pest biological control was on the other hand more clearcut, with however some exceptions. The diversity of responses to landscape can have several underlying causes. First, the functionality of crop covers is likely to differ according to land use intensity, i.e. levels of inputs, notably pesticides and fertilizers. Low-intensity agriculture enhances biodiversity both at farm and at landscape level (Rundlof and Smith 2006, Rundlof et al. 2008) and can promote biological control. In some of the study cases reported in this present analysis, we suspect that the effect of pesticide pressure on pest and natural enemies was so strong that it masked any potential effect of the landscape context (*17* Ricci et al. 2009). Overall, we would therefore expect to detect landscape effects in low intensity agriculture. This does not mean that the landscape context of fields has no impact even when pesticide pressure is high. Some studies show that it can partly buffer the negative effect of pesticide application as shown for grass strips which provide refuge for polyphagous carabids at times of pesticide application or the proportion of land under organic management around the field which has a positive effect on natural enemies and CBC effectiveness.

A second reason underlying the variability of results reported could be related to the fact that for some organisms, classifying the landscape into simple descriptors, i.e. area of crop-habitat and area of semi-natural habitat, is not relevant or sufficiently detailed as it bears no link to the functionality of these land-covers. First there could be a mismatch between the area of crop and the actual habitat that is being used by the organism, e.g. some generalist species might use different crop types or on the other hand, the fields of the crop habitat might be so intensively treated with pesticides that they become unsuitable for the organism. Second, the area of semi-natural habitats is sometimes reported as the sum of areas of different habitat types (woodland, grass, field margins) and organisms will generally not use all these habitats; contrarily it is sometimes reported only as the area of a single habitat type (e.g. woodland) which may not contain all resources needed by organisms that use complementary resources over the landscape. Such rough classification of land covers in collected studies may be due to the use of pre-existing land cover maps that were not meant for the purpose of conservation biological control, and to our poor knowledge of the ecology of pests and pest enemies.

Table 1. Cases of relationships between pest abundance and area of cultivated land in the landscape. The study ID refers to the References

Study ID	Pest species	*SIGN*	Sampled crop	Landscape variable	Buffer width
8	*Sitobion avenae, Metopolophium dirhodum, Rhopalosiphum padi*	+	winter wheat	% cultivated area	~50000m
11	*Autographa gamma*	+	spinach	% potato	600m
16	*Rhopalosiphum padi*	-	spring barley	% arable	400m, 25000m
16	*Rhopalosiphum padi*	-	spring barley	% perennial crop	400m, 25000m
19	*Sitobion avenae, Metopolphium dirhodum, Rhopalosiphum padi*	-	winter wheat	% arable	1500m
11	*Autographa gamma*	0	spinach	farmland area	600m
14	*Aphis fabae*	0	spinach	% of cultivated area	600m - 1200m
14	*Autographa gamma*	0	spinach	% of cultivated area	600m - 1200m
22	*Helicoverpa armigera*	0	maize	% maize	25000m *25000m
23	*Thrips tabaci*	0	sweet pepper	% greenhouse	1000m

Table 2. Cases of relationships between the direction of conservation biological control on pest population and area of cultivated land in the landscape. The study ID refers to the References

ID	Pest species	Natural enemy species	*SIGN*	Sampled crop	Landscape variable	Buffer width
2	*Mamestra brassicae*	*Trichogramma*	+	brussels sprout	% horticulture	1000m
2	*Mamestra brassicae*	predators	+	brussels sprout	% horticulture	1000m
16	*Rhopalosiphum padi*	Carabid beetles	-	spring barley	% perennial crop	400m, 25000m
16	*Rhopalosiphum padi*	Carabid beetles	-	spring barley	% arable	400m, 25000m
19	*Sitobion avenae, Metopolphium dirhodum, Rhopalosiphum padi*	*Aphidius, Praon, Ephedrus, Aphelinus, Toxares*	+	winter wheat	% arable	1500m
5	*Diauraphis noxia, Aphis helianthi*	*Aphelineus albipodus*	0	winter wheat	% of grass based vegetation	2800m ($25000m^2$)
5	*Diauraphis noxia, Aphis helianthi*	*Lysphlebus testaceipes*	0	winter wheat	% of grass based vegetation	2800m ($25000m^2$)
19	*Sitobion avenae, Metopolphium dirhodum, Rhopalosiphum padi*	*Alloxysta, Asaphes, Dendrocerus, Coruna, Phaenoglyphis, Diaeretiella*	0	winter wheat	% arable	1000m - 3000m
20	*Meligethes aeneus*	*Tersilochus heteroceus*	0	oilseed rape	% oilseed rape	500m - 6000m
20	*Meligethes aeneus*	*Phradis interstialis*	0	oilseed rape	% oilseed rape	500m - 6000m

Table 3. Cases of relationships between pest abundance and host crop area in the landscape. The study ID refers to the References

Study ID	Pest species	*SIGN*	Sampled crop	Landscape variable	Buffer width
4	*Leptinotarsa decemlineata*	+	Potato	% potato of preveous year	2000m
6	*Thrips tabaci*	+	Leek	% horticulture	5000m
7	*Rhophalosiphum padi*	+	Cereal	cereal area / maize area	50000m
9	*Delphacodes kuscheli*	+	Grassland	% winter pasture	2500m
17	*Cydia pomonella*	-	Orchard	% orchard	100m
21	*Lobesia botrana*	+	Vineyard	% vineyard	100m
21	*Empoasca vitis*	-	Vineyard	% vineyard	100m
21	*Lobesia botrana*	+	Vineyard	% vineyard	100m
21	*Empoasca vitis*	-	Vineyard	% vineyard	100m
23	*Frankliniella occidentalis*	+	sweet pepper	% greenhouse	1000m
24	*Ceutorhyncus napi, C. pallidactylus*	-	oilseed rape	% oilseed rape	800m
24	*Meligethes aeneus*	-	oilseed rape	% oilseed rape	1000m
15	*Rhophalosiphum padi*	0	spring barley	proportion of spring cereals to total cultivated area	400m
20	*Meligethes aeneus*	0	oilseed rape	% oilseed rape	500m - 6000m
21	*Eupoecilia ambiguella*	0	Vineyard	% vineyard	100m
21	*Scaphoideus titanus*	0	Vineyard	% vineyard	100m
22	*Ostrinia nubilalis*	0	Maize	% maize	admin. units
24	*Dasineura brassicae*	0	oilseed rape	% oilseed rape	100m-2000m

Table 4. Cases of relationships between the direction of conservation biological control on pest population and semi-natural area in the landscape. The study ID refers to the References

ID	Pest species	Natural enemy species	*SIGN*	Sampled crop	Landscape variable	Buffer width
2	*Mamestra brassicae*	*Trichogramma*	-	brussels sprout	% grassland	1000m
2	*Mamestra brassicae*	predators	-	brussels sprout	% forest	1000m
3	*Plutella xylostella*	*Diadegma* spp.	-	brussels sprout	% forest	1000m
12	*Aphis fabae*	parasitoids	-	tomato	% semi-natural	5000m, 1000m
13	*Pseudaletia unipuncta*	*Glyptapanteles militaris*	+	maize	% semi-natural	3200m *13900m
13	*Pseudaletia unipuncta*	*Meteorus* spp.	-	maize	% semi-natural	3200m *13900m
20	*Meligethes aeneus*	*Tersilochus heteroceus*	-	oilseed rape	% semi-natural	1500m
20	*Meligethes aeneus*	*Phradis interstialis*	-	oilseed rape	% semi-natural	1000m
1	*Acyrthosiphon pisum*	Carabid beetles	0	winter wheat	% forest	500m
13	*Pseudaletia unipuncta*	parasitoids	0	maize	% semi-natural	3200m *13900m

First, we expected that an increasing proportion of a given crop over the landscape would correlate with its pest abundance at least when the crop area would be sufficiently large . We did find some studies reporting such a positive trend, but almost as many showing no trend or the opposite trend. Independence of crop area and pest abundance may happen if part of the pest life cycle occurs outside the crop or if it depends on the crop area from the preceding year (e.g. the cereal aphid *Rhophalosiphum padi* needs the shrub *Prunus padus* to complete its lifecycle *15*Ostman 2002). This would particularly be the case at the beginning of pest infestation (e.g. the density of *Thrips tabaci* that colonizes sweet pepper greenhouses from surrounding arable fields was found independent of greenhouse density early in season, *23*Veres et al. 2008). Such independence may even explain some of the negative trends through a dilution effect in situations where a constant number of pest individuals at the landscape scale is distributed over a range of crop areas and the pest is thus locally less abundant when the crop area increases. This explanation may apply in particular to mobile pests such as pollen beetles (*24* Zaller et al. 2008). However, some authors reporting negative trends tend to favour an explanation based on pesticide intensity suggesting that the crop could represent an unfavourable habitat for the pest whose abundance could depend on small amounts of untreated hosts or alternative hosts. Positive correlations between pest abundance and crop area would be expected in extensive systems only.

Table 5. Cases of relationships between pest abundance and semi-natural area in the landscape. The study ID refers to the References

Study ID	Pest species	*SIGN*	Sampled crop	Landscape variable	Buffer width
6	*Thrips tabaci*	-	leek	% forest	5000m
12	*Empoasca* sp.	+	tomato	% semi-natural	1000m, 5000m
12	*Aphis fabae*	-	tomato	% semi-natural	1000m, 5000m
12	*Myzus persicae*	-	tomato	% semi-natural	1000m, 5000m
14	*Aphis fabae*	-	spinach	% forest	1200m
14	*Aphis fabae*	+	spinach	% vegetation strip	600m
18	*Ostrinia nubilalis*	-	forest	% forest	Ecoregion
18	*Plathypena scabra*	-	forest	% forest	Ecoregion
18	*Crambus agitatellus*	-	forest	% forest	Ecoregion
18	*Lithacodia muscosula*	-	forest	% forest	Ecoregion
20	*Meligethes aeneus*	-	oilseed rape	% semi-natural	1500m
22	*Helicoverpa armigera*	-	maize	% semi-natural	admin. Unit
22	*Ostrinia nubilalis*	-	maize	% semi-natural	admin. Unit
24	*Dasineura brassicae*	+	oilseed rape	% forest	200m
24	*Meligethes aeneus*	+	oilseed rape	% forest	1000m
10	Legume weevils	0	alfalfa	% forest	1000m
10	*Hypera postica*	0	alfalfa	% forest	1000m
11	*Autographa gamma*	0	spinach	% forest	600m
12	*Frankliniella occidentalis*	0	tomato	% semi-natural	1000m, 5000m
12	*Epitrix hirtipennis*	0	tomato	% semi-natural	1000m, 5000m
12	*Helicoverpa zea*	0	tomato	% semi-natural	1000m, 5000m
14	*Autographa gamma*	0	spinach	% forest	600m - 1200m
15	*Rhopalosiphum padi*	0	spring barley	% forest	400m
24	*Ceutorhyncus napi, C. pallidactylus*	0	oilseed rape	% forest	2000m

Second, we tested that increasing area of semi-natural habitats leads to increased predation or parasitism. Such a relationship was expected because biodiversity and/or the abundance of pests' natural enemies in fields generally correlate to the amount of non-crop habitats at landscape scale (Bianchi et al. 2006, Tscharntke et al. 2007, Attwood et al. 2008). Natural habitats may indeed provide food and sites for reproduction or overwintering. However, the potential of these elements to support pest enemies also depends on their quality and management (*2* Bianchi et al. 2005). Here, we found a trend for increasing area of semi-natural elements to indeed increase CBC: the relationship was not significant in two cases, negative in only one case and positive in seven cases. Moreover, the only negative relationship that was observed was one case in five years (*13*Menalled et al. 2003). There are a number of reasons for which this relationship may not be positive. In very intensive landscapes, the regional pool of natural enemies may not be sufficient for populations of pest enemies to build up (Tscharntke et al. 2007). Under these circumstances, increasing semi-natural area may have no or little effect. Further, conservation of species enemy diversity does not always increase biological control because of intraguild predation or the absence of niche complementarity among enemies (Bianchi et al. 2006). Finally, landscapes with a high proportion of non-crop habitats may also host more alternative preys and generalist predators may switch to food resources other than pests (16 Ostman et al. 2001).

Thirdly, we expected that increasing semi-natural areas in the landscape would lead to a decreasing pest abundance, because semi-natural areas (i) increase in-field populations of natural enemies, (ii) tend to increase CBC (our results), (iii) may be unsuitable habitats for pests (e.g. forests for lepidopteran pests *18* Summerville 2004, *22* Veres et al. 2006), (iv) may reduce crop source pool in the landscape (for thrips: *6* den Belder et al. 2002, for aphids: *12* Letourneau and Goldstein 2001, *14* Meyhofer et al. 2008) and (v) may also be barriers for isolation (for thrips: *6* den Belder et al. 2002).

We did not find such relationship. Here, we suggest that the functionality of the given semi-natural areas should be considered as natural habitats may provide resources to pests. Grasslands for example may be sources of leafhoppers and cereal thrips early in the season (*12* Letourneau and Goldstein 2001) and woody areas could serve as overwintering sites for pests such as pollen beetle, or could improve overwintering in other semi-natural areas by changing microclimatic conditions (*24* Zaller et al. 2008). A similar need for considering crop functionality may explain why we did not find an excess of negative relationships between CBC and landscape scale cultivated area. There are both suitable and unsuitable periods in crops for natural enemies in every growing season because of management practices, or variation of food resource. The agrobiont species, in particular, take ecological advantage of tolerating human disturbance, recolonize fields time after time (Wissinger 1997) and profit from the high amount of available food resource in the field (Rand et al. 2006). Resource availability is the reason given by authors that observed positive relationships between CBC and landscape scale cultivated area.

Results confirmed the suspected suppressive effect of landscape scale amounts of semi-natural areas on in-field pests: landscapes with higher proportions of semi-natural areas exhibited lower pest abundance or higher pest control in fields. Contrarily, there was no clear direction in relationships between pests and pest control and landscape when the latter was described as the overall proportion of cultivated area or as that of crops host to particular pests. The analysis of original articles indicates that this lack of directionmay be due to the diversity of land use intensity in the studied landscapes and to a too rough categorizing of land covers. This pleads for a better consideration of the functionality of crops and of their management in landscapes.The ultimate aim of landscape management as far as crop protection is concerned would be to contribute to sustainable crop production for all crops grown over a landscape by designing pest suppressive landscapes that minimize the need for pesticides to control pests. Our analysis indicates that increasing the proportion of semi-natural areas over the landscape would contribute to the design of such landscapes. The analysis also shows contrasted relations between in-field pest abundance and the area of their host crop over the landscape. This may either be indicative of an absence of effect or of different processes acting in different cases. More case studies are needed before a general conclusion can be drawn on that question. Main gaps in existing research appear to be the generally poor consideration paid to the possible functions of crops and their management in landscapes (e.g. possibly providing resources for pest enemies at specific times) and the absence of multi-pest, multi-crops studies over single landscapes. Further, while the number of studies addressing the impact of landscape management on pest control, and not only on natural enemy populations, is increasing, there are still too few studies directly investigating the impact of landscape on crop performance (i.e. crop damage or yield).

Discussing the impact of the cropped habitat on pest abundance and on conservation biological control, we concluded that the agricultural management intensity at regional scale might effect the efficiency of the natural enemies. The main habitat for the effective natural enemies is the crop itself, but there are unsuitable periods when they need alternative habitats too. The spontaneous colonization of fields by predators and parasitoids depends both on the amount of alternative habitats and on the quality of cropped habitat due to the management intensity in the cropping system typical for the region.

2.2 SPATIAL-TEMPORAL DYNAMICS OF *ORIUS* SPP. (HETEROPTERA: ANTHOCORIDAE) ABUNDANCE IN THE LANDSCAPE

2.2.1 MATERIAL AND METHODS

The three year survey was conducted on poison hemlock (*Conium maculatum L.,*Veres et al 2010, Veres 2010) in the landscape of 5 neighbored villages located in the Jászság region (Hungary, N47 36.449 E19 39.929, Boldog, Jászfényszaru, Jászfelsőszentgyörgy, Pusztamonostor, Szentlőrinckáta). Plants were chosen randomly nearby roads all over the landscape, keeping a distance of minimum 200 meters between sampling points. The flower-umbrella of the plant was considered as a sampling unit, out of which arthropodswere shaken into an adopted sweeping net and conserved in ethyl-alcohol. The sampling was carried out for 3 years when hemlock started flowering and took 3 days in a row (28-30th July 2005, 4-6th July 2006, 18-20th of June 2007). We collected 164 samples in 2005, 155 samples in 2006, 138 samples in 2007. *Orius* adult abundance in total and at species level (i.e. *Orius niger*, *Orius minutus*) was measured (Péricart 1972). The location of the sampling points was marked by GPS. The mapping of *Orius* habitats was carried out using Esri ArcGIS 9.2. geographical information system. Landscape features were digitized from a 0.5m resolution color digital orthophoto (acquisition date 2005, FÖMI archive) into CLC 50 categories (FÖMI, Büttner et al. 2000). To create the map of potential habitats, features of CORINE categories were selected into a new layer called SEMI-NATURAL. Buffers in a distance of 1000m were calculated around each sampling point for each species and year, and intersected with the layer SEMI-NATURAL. The area of each habitat polygon was calculated in the intersected layers and summed up to the points.

Differences in total abundance between years were statistically estimated using Welsh-t test (package stats R2.1.1). SADIE (Spatial Analysis by Distance IndicEs) statistical analysis method (Perry 1995) was applied to characterize the spatial distribution of *Orius* abundance (I_a average distance flow) and to determine the degree of association of insect pattern to the habitat pattern (χ, index of association).

2.2.2 RESULTS

In total 4176 *Orius* adults out of 457 poison hemlock plants were collected in this region during the three study years. The individuals were classified into five *Orius* species, out of which *O. niger* was highly dominant. Further individuals of *O. minutus*, *O. majusculus*, *O. vicinus* and *O. horvathi* species were recorded.Regarding conservation biological control in greenhouse sweet pepper, *O. niger* can be considered as the most relevant species, since it was reported to colonize greenhouses spontaneously (Bosco et al. 2008, Bán et al. 2009),and to be highly mobile with a high ability to search resources actively in the agricultural landscape. The total *Orius* abundance was low in 2005 and in 2006, and was significantly higher in 2007 than both years, so seasonal differences have to be considered (Figure 2., P. 17.). 2005 was an extremely cold year, with cold winter and spring (T_{mean}: 9.7 ^{o}C, Bihari et al. 2008). The year 2006 was also colder than the average, but warmer than 2005 (T_{mean}: 10.3 ^{o}C). In contrary, the year 2007 was extremely hot and dry (T_{mean}: 11.75 ^{o}C).

Besides the direct seasonal effects such as temperature, also the differences in the amount of prey might influence indirectly *Orius* populations. Seasonal differences were detected not only in population size, but also in distribution pattern. The total abundance was aggregated in 2007 (Ia=2.392, p=0.003, Table 6., P. 19.), but not in 2005 (I_a=1.418; p=0,086,)and 2006 (I_a=1.318; p=0,121). The highly dominant *O. niger* showed similarly no trend in 2005 (Ia=1.353, p=0.115), but was aggregated in the sampled landscape in 2006 (Ia=1.582, p=0.048) and in 2007 (Ia=2.656, p=0.032). The abundance values of *O. minutus* were randomly distributed in 2005 and 2007, while in 2006 there were not enough individuals found to do the tests. The dominant *O. niger* is likely distributed aggregated, not randomly in the landscape, following the resource pattern dynamics. This assumption is supported by the fact that they respond to odors of thrips-infected plants (Carvalho et al. 2011), search actively for prey-hotspots, and leave plants of low prey density (Montserrat et al. 2004)

We found further significant results when the abundance patterns were related to the patterns of semi-natural area. In the cold year 2005, both the total *Orius* abundance (χ= 0.2142, p=0.0215, Table 7., P. 19.), and the *O. niger* abundance (χ= 0.2174, p=0.0230) were associated to the semi-natural areas. In the slightly warmer year 2006, the association was significant only for the *O. niger* species (χ= 0.1996, p=0.0063). *Orius* species, especially *O. niger* are likely to be related to semi-natural areas, where they can overwinter with a high probability. In contrary, in the extreme hot and dry year 2007 both the total *Orius* abundance (χ= -0.2113, p=0.989), and the *O. niger* abundance (χ= -0.2467, p=0.997) were dissociated to the semi-natural areas. In this year, the *Orius* individuals were likely dispersed from the overwintering sites and associated to other resources in the landscape. They were aggregated near Jászfényszaru, and not near Jászfelsőszentgyörgy, where semi-natural areas are present. The differences between seasons in terms of temperature and food resource have affected their spatial distribution and not only their population size. In contrary,*O. minutus* individuals did not show any significant relationship.

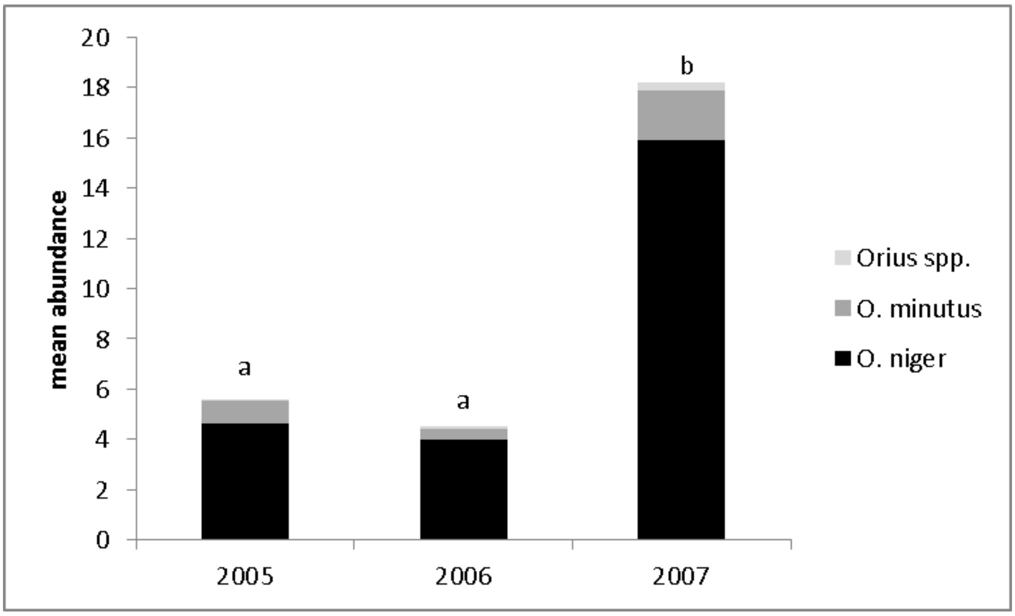

Figure 2.
Mean *Orius* adult abundance on poison hemlock (*Conium maculatum L.*) in the different years (Region Jászság). The columns marked by different letters are significantly different (level p<0.05)

Our results suggest that the *Orius* population is related to the semi-natural areas at landscape level, where they overwinter (Saulich and Musolin 2009), but they spread out and develop their population on other landscape features depending on the season. We suppose that they overwinter at semi-natural areas, then colonize cultivated areas, where they reproduce and enhance their population by taking ecological advantage of the high amount of food resource available. This population dynamic is delayed by cold weather and low prey density, and enhanced in hot seasons.

Bán et al. (2009) showed a higher number of *Orius* individuals in the greenhouses surrounded by arable fields at Jászfelsőszentgyörgy in 2006, and at Jászfényszaru in 2007, which correspond to our results on *Orius* distribution in the landscape. We use poison hemlock as an indicator species, so for generalization further studies might be necessary.

2.3 New Results for Science

Results of the literature review:

1. Results of the literature review suggestthat studies investigating the impact of cultivated and semi-natural areas or studies investigating pest abundance or CBC had similar probabilities of reporting significant landscape effects.
2. Based on the studies published until 2008, there was no clear direction in relationships between pests and pest control and landscape when the latter was described as the overall proportion of cultivated area or as that of crops hosting particular pests.
3. Results confirmed the suspected suppressive effect of landscape scale amounts of semi-natural areas on in-field pests: landscapes with higher proportion of semi-natural areas exhibited lower pest abundance or higher pest control in fields.

Results of the *Orius* survey:

4. Seasonal differences affected the *Orius* population, not only in population size, but also in distribution pattern.
5. The spatial distribution of *Orius niger* is not random.
6. We found further significant results when the abundance patterns were related to the patterns of semi-natural area, differing according to the season. In colder years like 2005 and 2006 *Orius niger* population was associated to semi-natural areas, while in the hot and dry year 2007 was dissociated.

Table 6. Spatial distribution of *Orius* spp in the landscape. Jászság (2005. 2006. 2007)

	***Orius* total**	***O. niger***	***O. minutus***
2005			
I_a	1.418	1.353	1.001
p_a	0.0865	0.1154	0.3942
Vi	1.8881	1.298	1.254
$p_{(mean\ vi)}$	0.0096	0.1442	1.667
Vj	-1.338	-1.295	-0.982
$p_{(mean\ vj)}$	0.0865	0.1218	0.4199
2006			
I_a	1.318	**1.582**	NA
p_a	0.1211	**0.0481**	NA
Vi	1.067	**1.412**	NA
$p_{(mean\ vi)}$	0.3269	**0.0897**	NA
Vj	-1.267	**-1.597**	NA
$p_{(mean\ vj)}$	0.1506	**0.0513**	NA
2007			
I_a	**2.420**	**2.656**	0.5737
p_a	**0.0032**	**0.0032**	0.881
Vi	**-2.764**	**2.453**	0.943
$p_{(mean\ vi)}$	**0.000**	**0.0064**	0.5481
Vj	**2.613**	**-3.015**	-0.776
$p_{(mean\ vj)}$	**0.000**	**0.000**	0.8429

I_a *average distance flow*, p_a, associated probability, significant if p<0.05 (in bold) *vi*, *vj cluster index*, $p_{(mean\ vi)}$, $p_{(mean\ vj)}$ associated probability of vi and vj , significant, if *p*<0.05 NA no data

Table 7. Association of *Orius* abundance pattern to the pattern of semi-natural areas, Jászság (2005, 2006, 2007)

	***Orius* total**	***O. niger***	***O. minutus***
2005			
X	**0.2142**	**0.2174**	0.1076
P	**0.0215**	**0.0230**	0.1373
relation	**association**	**association**	Non sign
2006			
X	1.363	**0.1996**	NA
P	0.0473	**0.0063**	NA
relation	Non sign	**association**	NA
2007			
X	**-0.2113**	**-0.2467**	0.0333
P	**0.989**	**0.9979**	0.3902
relation	**dissociation**	**dissociation**	Non sign

χ association index
*p*associated probability, significant if *p*<0.025 or *p*>0.975 , (in bold)

NA no data

2.4 SUGGESTIONS

Our results suggest that the abundance and the spatial distribution of *Orius* species depends on the changes of flower-resource pattern and to the related prey amount, thus we suggest that future studies should describe landscape according to these resources, and to clarify the role of each crop in the ecology of *Orius* species. In these studies is relevant to take into consideration the landscape context of the crop and the spatial arrangement of the habitat. Satellite image series and aerial photographs are adequate tools to describe land cover and classify crops. The presence of semi-natural areas in the landscape is important for *Orius* species, but the mass reproduction and the enhancement of the population are likely to be related to cultivated areas. These dynamics are delayed in cold seasons, but in hot seasons especially the *O. niger* species takes ecological advantage of the food resources of cultivated areas. Therefore in an IPM point of view we suggest to consider that the colonization of fields and the efficient conservation biological control can be expected mostly in hot seasons, and that the presence of arable fields in the surrounding of the greenhouses is favorable. For sustainable development of agro-environmental schemes it is required to consider that besides semi-natural areas, also cultivated areas have an important role in the efficiency of natural enemies and conservation biological control at landscape level. Further studies are needed to investigate the relationship of *Orius* population size in the landscape and the colonization of greenhouses, especially in relation to thrips control efficacy, in order to develop decisions support systems based on these evidences. However *Orius* species are assumed to be highly mobile, there are no quantitative data available yet on theirmigration potential, so even if their population size at various landscape features can be estimated, it is hardly possible to forecast the amount of *Orius* individuals colonizing the crops.

Both the literature review and the experimental study suggest that conservation biological control in typical agricultural landscape is based on a cyclic colonization model rather than on spill-over of natural enemies from semi-natural areas. The key natural enemies are likely to use semi-natural areas as overwintering sites and shelter habitats, from where they spread out and reproduce at cultivated areas. I suggest to describe the cyclic colonization model in the different cropping systems and to identify the key natural enemies,but also to study the interaction of more extensive arable crops and more profitable horticultural crops.

The ultimate aim of landscape management as far as crop protection is concerned would be to contribute to sustainable crop production for all crops grown over a landscape by designing pest suppressive landscapes that minimize the need for pesticides to control pests. Our analysis indicates that increasing the proportion of semi-natural areas over the landscape would contribute to the design of such landscapes. The analysis also shows contrasted relations between in-field pest abundance and the area of their host crop over the landscape. This may either be indicative of an absence of effect or of different processes acting in different cases. More case studies are needed before a general conclusion can be drawn on that question.

The fact that most landscape studies are carried out in intensively managed agricultural landscapes makes it necessary to essay pest-natural enemy dynamics of future sustainable landscapes. The reanalysis of archive data can provide future perspectives for a better understanding. Main gaps in existing research appear to be the generally poor consideration of the possible functions of crops and their management in landscapes (e.g. possibly providing resources for pest enemies at specific times) and the absence of multi-pest, multi-crop studies over single landscapes. Finally, while the number of studies addressing the impact of landscape management on pest control, and not only on natural enemy populations, is increasing, there are still too few studies directly investigating the impact of landscape on crop performance (i.e. crop damage or yield).

2.6 References

1 Ameixa, O., Kindlmann, P., 2008. Agricultural policy-induced landscape changes: effects on carabid abundance and their biocontrol potential. Ecological Modelling 213: 308-318

Attwood, S.J., Maron, M., House, A.P.N., Zammit, C., 2008. Do athropod assemblages display globally consistent responses to intensified agricultural land use and management. Global Ecol. Biogeogr. 17, 585-599.

Bán, G., Tóth, F., Orosz, Sz., 2009. Diversifying arthropod assemblages of greenhouse pepper – preliminary results. Acta Phytopathologica et Entomologica Hungarica 44, 101–110.

Bianchi, F., Booij, C.J.H., Tscharntke, T., 2006. Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural pest control. Proc. R. Soc. B-Biol. Sci. 273, 1715-1727.

3 Bianchi, F., Goedhart, P.W., Baveco, J.M., 2008. Enhanced pest control in cabbage crops near forest in The Netherlands. Landsc. Ecol. 23, 595-602.

2 Bianchi, F., van Wingerden, W., Griffioen, A.J., van der Veen, M., van der Straten, M.J.J., Wegman, R.M.A., Meeuwsen, H.A.M., 2005. Landscape factors affecting the control of *Mamestra brassicae* by natural enemies in Brussels sprout. Agric. Ecosyst. Environ. 107, 145-150.

Bihari, Z., Lakatos, M., Szalai, S. és Szentimrey, T., 2008. Magyarország éghajlatának néhány jellemzője 2005-2007, OMSZ Kiadvány, www.met.hu

4 Boiteau, G., Picka, J.D., Watmough, J., 2008. Potato field colonization by low-density populations of Colorado potato beetle as a function of crop rotation distance. J. Econ. Entomol. 101, 1575-1583.

Bosco, L., Giacometto, E. and Tavella, L., 2008. Colonisation and predation of thrips (Thysanoptera: Thripidae) by *Orius* spp (Heteroptera: Anthocoridae) in sweet pepper greenhouses in Northwest Italy. Biological Control 44, 331-340.

5 Brewer, M. J., Noma, T., Elliott, N. C., Kravchenko, A. N., Hild, A. L. 2008. A landscape view of cereal aphid parasitoid dynamics reveals sensitivity to farm- and region-scale vegetation structure. European Journal of Entomology 105, 467-476

Büttner, G., Bíró, M., Maucha, M., Petrik O., 2000. Land Cover mapping at scale 1:50.000 in Hungary: Lessons learnt from the European CORINE programme, 20th EARSeL Symposium, 14-16 June 2000, In: A decade of Trans-European Remote Sensing Cooperation, 25-31.

Carvalho, L. M., Bueno, V. H. P., Castane, C., 2011. Oflactory response towards its prey *Frankliniella occidentalis* of wild and laboratory-reared *Orius insidiosus* and *Orius laevigatus*, J. Appl. Entomol. 135, 177-183.

6 den Belder, E., Elderson, J., van den Brink, W.J., Schelling, G., 2002. Effect of woodlots on thrips density in leek fields: a landscape analysis. Agric. Ecosyst. Environ. 91, 139-145.

7 Fabre, F., Plantegenest, M., Mieuzet, L., Dedryver, C.A., Leterrier, J.L., Jacquot, E., 2005. Effects of climate and land use on the occurrence of viruliferous aphids and the epidemiology of barley yellow dwarf disease. Agric. Ecosyst. Environ. 106, 49-55.

8 Freier, B., Triltsch, H., Mowes, M., Moll, E., 2007. The potential of predators in natural control of aphids in wheat: Results of a ten-year field study in two German landscapes. Biocontrol 52, 775-788.

*9*Grilli, M.P., Bruno, M., 2007. Regional abundance of a planthopper pest: the effect of host patch area and configuration. Entomol. Exp. Appl. 122, 133-143.

10 Holland, J., Fahrig, L., 2000. Effect of woody borders on insect density and diversity in crop fields: a landscape-scale analysis. Agriculture Ecosystems & Environment 78, 115-122.

11 Klug, T., Gathmann, A., Poehling, H.-M., Meyhofer, R., 2003. Area-dependent effects of landscape structure on the colonisation of spinach cultures by the silver Y moth (*Autographa gamma* L., Lepidoptera: Noctudidae) in Western Germany. IOBC wprs Bulletin 26, 77.

12 Letourneau, D.K., Goldstein, B., 2001. Pest damage and arthropod community structure in organic vs. conventional tomato production in California. J. Appl. Ecol. 38, 557-570.

Lundgren, J., Fergen, J. K. and Riedell, W. E., 2008. The influence of plant anatomy on oviposition and reproductive success of the omnivorous bug *Orius insidiosus*, Anim. Behaviour 75, 1495-1502.

Lundgren, J., G., Wyckhuys, K., A., G., Desneux, N., 2009. Population responses by *Orius insidiosus* to vegetational diversity, BioControl 54, 135-142

13 Menalled, F.D., Costamagna, A.C., Marino, P.C., Landis, D.A., 2003. Temporal variation in the response of parasitoids to agricultural landscape structure. Agric. Ecosyst. Environ. 96, 29-35.

14 Meyhofer, R., Klug, T., Poehling, H.-M., 2008. Are landscape structures important for the colonization of spinach fields by insects? IOBC/wprs Bulletin 34, 69-72.

Montserrat, M., Albajes, R., Castane, C., 2004. Behavioral responses of three plat-inhibiting predators to different prey densities, Biol. Control 30, 256-264.

15 Ostman, O., 2002. Distribution of bird cherry-oat aphids (*Rhopalosiphum padi* L) in relation to landscape and farming practices. Agriculture Ecosystems & Environment 93, 67-71.

16 Ostman, O., Ekbom, B., Bengtsson, J., 2001. Landscape heterogeneity and farming practice influence biological control. Basic Appl. Ecol. 2, 365-371.

Péricart, J., 1972. “Hémiptéres, Anthocoridae, Cimicidae et Microphysidae de l’OuestPaléarctique,” in *Faune de l’Europe et du Basin Méditerranéen, No. 7* (Paris, 1972).

Perry, J.N., 1995. Spatial analysis by distance indices. Journal of Animal Eco. 64, 303-314.

Rácz, V. 1989. Poloskák (Heteroptera) szerepe magyarországi kukoricások életközösségében. Kandidátusi értekezés, Budapest.

R Development Core Team, 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Rand, T.A., Tylianakis, J.M., Tscharntke, T., 2006. Spillover edge effects: the dispersal of agriculturally subsidized insect natural enemies into adjacent natural habitats.Ecol. Lett. 9, 603-614.

17 Ricci, B., Franck, P., Toubon, J.F., Bouvier, J.C., Sauphanor, B., Lavigne, C., 2009. The influence of landscape on insect pest dynamics: a case study in southeastern France. Landsc. Ecol. 24, 337-349.

Rundlof, M., Bengtsson, J., Smith, H.G., 2008. Local and landscape effects of organic farming on butterfly species richness and abundance. J. Appl. Ecol. 45, 813-820.

Rundlof, M., Smith, H.G., 2006. The effect of organic farming on butterfly diversity depends on landscape context. J. Appl. Ecol. 43, 1121-1127.

SADIE, Spatial Analysis for distance Indices, http://www.rothamsted.ac.uk/pie/sadie/SADIE_home_page_1.htm

Saulich, AKh., Musolin, D.L., 2009. Seasonal development and ecology of Anthocorids (Heteroptera, Anthocoridae). Entomologicheskoe Obozrenie, 88, 257–291 (orosz nyelven, angol összefoglalóval). [angol fordítás: Entomological Review, 2009, 89, 501–528]

18 Summerville, K.S., 2004. Do smaller forest fragments contain a greater abundance of Lepidopteran crop and forage consumers? Environ. Entomol. 33, 234-241.

19 Thies, C., Roschewitz, I., Tscharntke, T., 2005. The landscape context of cereal aphid-parasitoid interactions. Proc. R. Soc. B-Biol. Sci. 272, 203-210.

20 Thies, C., Steffan-Dewenter, I., Tscharntke, T., 2008. Interannual landscape changes influence plant-herbivore-parasitoid interactions. Agric. Ecosyst. Environ. 125, 266-268.

Tscharntke, T., Bommarco, R., Clough, Y., Crist, T.O., Kleijn, D., Rand, T.A., Tylianakis, J.M., van Nouhuys, S., Vidal, S., 2007. Conservation biological control and enemy diversity on a landscape scale. Biol. Control 43, 294-309.

21 van Helden, M., Fargeas E., Fronzes M., Maurice O., Thibaud M., Gil F., Pain G., 2006. The infuence of local and landscape characteristics on insect pest population levels in viticulture. IOBC/wprs Bulletin 29, 145-148.

Veres, A., 2010. The relation of minute pirate bug abundance (*Orius* spp.) to the amount of suitable habitats in the landscape analysed using GIS, NyME GEO, szakmérnökidolgozat

Veres, A., Kotán, A., Fetykó, K., Orosz, Sz. and Tóth, F., 2010. Innovative methods for measuring *Orius* spp. (Anthocoridae) abundance at a landscape scale. IOBC wprs Bulletin 56, 135-138

23 Veres, A.,Tóth, F., Orosz , S., Kristóf, D., Fetykó, K., 2008. Spatial analysis of greenhouse density in relation to western flower thrips (*Frankliniella occidentalis*), onion thrips (*Thrips tabaci*) and minute pirate bug (*Orius* spp;) population in greenhouses. IOBC/wprs Bulletin 34, 129-132.

22 Veres, A., Tóth, F., Szalkai, G., 2006. The damage pattern of *Helicoverpa armigera* and *Ostrinia nubilalis* in relation to landscape attributes - comparing two databases of Hungary at country level. IOBC/wprs Bulletin 29, 153-156.

Wissinger, S.A., 1997. Cyclic colonization in predictably ephemeral habitats: A template for biological control in annual crop systems. Biol. Control 10, 4-15.

24 Zaller, J.G., Moser, D., Drapela, T., Schmoger, C., Frank, T., 2008. Effect of within-field and landscape factors on insect damage in winter oilseed rape. Agric. Ecosyst. Environ. 123, 233-238.

Publications in English:

Veres, A., Petit, S., Conord, C., Lavigne, C. (2011): Does landscape composition affect pest abundance and their control by natural enemies? A review. Agriculture Ecosystems and Environment (doi:10.1016/j.agee.2011.05.027)

Vasileiadis, V.P., Sattin, M., Otto, S., **Veres, A.**, Pálinkás, Z., Pons, X., Kudsk, P., van der Weide, R., Czembor, E., Moonen, C., and Kiss, J. (2011): Crop protection in European maize-based cropping systems: current practices and recommendations for innovative Integrated Pest Management. Agricultural Systems (doi:10.1016/j.agsy.2011.04.002)

Publications in Hungarian:

Veres, A., Lavigne, C., Petit, S., Conord, C., Moonen, C., Bohan, D., Kiss, J., Tóth, F., Szalai, M. (2010): Élőhelyeknövényvédelmiszerepe a mezőgazdaságitájban (The role of cropped and semi-natural habitats in crop protection at landscape level),Növényvédelem 46 (10): 481-491

Bán, G., Pintér, A., Fetykó, K., Orosz, Sz., **Veres**, **A.**, Tóth, F. (2010): A betelepítettvegyesízeltlábú-együttesfelhasználásilehetősége a hajtatott paprika biológiaivédelmében (The potential of artificially introduced arthropod assemblages in the biological control of greenhouse pepper),ÁllattaniKözlemények (2010) 95(1): 11–23.

Proceedings in English:

Petit, S., Lavigne, C., Ferguson, A., Tixier, P., Bohan, D., Denholm, I., Otto, S., Alomar, O., **Veres, A.**, Eggenschiwiler, L., Bocci, G., Moonen, C., Golla B.(2010): Conservation biological control at the landscape level: measuring and modelling, IOBC wprs Bulletin Vol. 56 87-93

Veres A., Petit S., Conord, C., Lavigne C. (2010): A literature review on impacts of landscape characteristics on densities of pests and their regulation by natural enemies, IOBC wprs Bulletin Vol. 56 129-133

Veres, **A**., Kotán, A., Fetykó, K., Orosz, Sz., Tóth, F. (2010): Innovative methods for measuring *Orius* spp. (Anthocoridae) abundance at landscape scale, IOBC wprs Bulletin Vol. 56 135-138

Veres, **A.,** Tóth, F., Orosz, Sz., Kristóf, D., Fetykó K. (2008): Spatial analysis of greenhouse density in relation to western flower thrips (*Frankliniellaoccidentalis*), onion thrips (*Trips tabaci*) and minute pirate bug (*Orius spp.*) population in greenhouses, IOBC wprs Bulletin Vol. 34 129-132

Veres, A., Tóth, F., Szalkai, G. (2006) The damage pattern of *Helicoverpaarmigera*and *Ostrinianubilalis* on maize in relation to landscape attributes – comparing two database of Hungary at national level, IOBC wprs Bulletin Vol. 29 (6) 153-156

Tóth, F., **Veres, A.**, Orosz, Sz., Fetykó, K., Brajda, J., Nagy, A., Bán, G., Zrubecz, P., Szénási, A. (2006): Landscape resources vs. commercial biocontrol agents in protection of greenhouse sweet pepper – a new exploratory project in Hungary IOBC wprs Bulletin Vol. 29 (6) 129-132