Sociobiology 65(4): 603-611 (October, 2018) Special Issue DOI: 10.13102/sociobiology.v65i4.3370

Sociobiology
An international journal on social insects

RESEARCH ARTICLE - BEES

Diversity of Flower Visiting Insects in Dry Grasslands and Vineyards Close to the City of Vienna with Special Focus on Wild Bees

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Article History

Edited by
Kleber Del Claro, UFU, Brazil
Cândida Aguiar, UEFS, Brazil
Received 25 April 2018
Initial acceptance 28 June 2018
Final acceptance 13 July 2018
Publication date 11 October 2018

Keywords
Organic farming, flower cover, flower strips.

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Abstract

Interactions between flower visiting insects and nectar resp. pollen producing plants belong to the most relevant in terrestrial ecosystems. Their diversity and dominance relationship are important indicators for the stability and functionality of ecosystems and belong to the high ranking ecosystem services. Potential pollinators should be strongly concerned especially regarding anthropogenic impacts on habitats. We studied the diversity and quantities of flower visiting insects with special focus on wild bees (Apiformes) in two locations near the city of Vienna (Austria). Insect sampling occurred from May until July 2015 every two weeks parallel to the vegetation surveys incl. records of the cover of flowering plants. In each location patches of semi-natural grassland as well as flowering strips within vineyards were investigated. We found a significant correlation between the number of insects or insect taxa (especially for Hymenoptera) and the current flower cover. In some cases flowering strips in vineyards harbor higher numbers of insects and higher diversity of bee species than the semi-natural grassland due to temporarily higher values of flower cover. However, grassland patches provide a much more constant supply with nectar producing plants replacing each other in their flowering phase during the season. In contrast, flowering strips are often dominated by one or a few short-lived sown plants, which is of advantage for some oligolectic bees specialized on Brassicaceae or Fabaceae. Flowering strips within organically farmed vineyards are more similar to semi-natural grassland regarding the diversity of flower visiting insects than to conventionally farmed vineyards.

Introduction

Interactions between flowering plants and flower-pollinating insects belong to the most significant in the terrestrial synecology (Richards, 1978; Proctor et al., 1996). Diversity and local distribution resp. commonness or rarity of both plants and insects are strongly dependent on the development and integrity of these relationships (e.g. Fontaine et al., 2006).

In the surrounding of the city of Vienna open semi-dry grasslands are one of the most important hot spots of biodiversity for both plants and insects (Adler & Mrkvicka, 2003). But their part in the landscape is comparatively small, and patches of grassland are in most cases strongly isolated from each other by the surrounding forests, settlement infrastructure and agricultural landscapes including arable fields and vineyards. Fragmentation and isolation of biotopes lead to the reduction of their functionality as habitat and dispersal corridors for insects (Tscharntke et al., 2002; Garibaldi et al., 2011). Moreover, intensive agriculture presumes the application of pesticides, which either leads to the reduction of insect diversity and quantity. One of the expected consequences could be pollination limitation (reduction of fruit setting rate due to insufficient pollination, Calvo & Horvitz, 1990; Jennersten & Nilsson, 1993; Larson & Barrett, 2000). Lack of pollinators is relevant not only for plant species diversity and population stability of rare and endangered semi-dry and dry grassland herbs, but also for the entire agricultural production and has a clear economical value (Klein et al., 2007; Neumayer, 2011).

Open access journal: http://periodicos.uefs.br/ojs/index.php/sociobiology
ISSN: 0361-6525

Bee species (Apiformes) are especially sensitive to the decline of insect-pollinated plants in the landscape (Biesmeijer et al., 2006) and thus are good indicators for the stability and integrity of plant/pollinator interactions and ecosystem services (Burkle et al., 2013).

The cultural landscape of low mountains around the city of Vienna (parts of Vienna Forest, so called Wiener Hausberge - Leopoldsberg, Nussberg, Bisamberg) was significantly changed in the last decades. In some parts agricultural use (mainly in form of vineyards) was strongly intensified, while at the same time formerly moderately used grassland areas became abandoned and are now covered by shrubs or forest. In both cases the attractiveness of areas for pollinators has been reduced. Some authors (see e.g. Haaland et al., 2011) express the expectation, that flower strips within or besides the vineyards could serve as important step-stone biotopes and feeding grounds for bees and other plant pollinating insects. In these functions and ecosystem services flower strips would complete or even replace the species-rich grasslands formerly present in the area in high percentage. However, flowering strips are artificial sites with significant differences to (semi-) natural grasslands. Following critical points can be mentioned in this context: (i) seed mixtures for flower strips usually include only a few dominant, but short-lived species which offer nectar and pollen for a rather narrow, restricted time span (van Elsen et al., 2007; Rundlöf et al., 2014); (ii) the seed mixtures for flower strips often include alien species or genetic varieties, which are either less adapted to local conditions or are potential invaders with a negative impact for the resident biota (Keller et al., 2000); (iii) flower strips are involved in agricultural production and are affected by the application of pesticides and mineral fertilizers together with the wine rows. Mowing of the flower strips is also linked to the demands of crop production, which means that mowing occurs earlier and more frequently than in the grassland and shorten significantly the flowering period of plant species and their offer of nectar and pollen (Bruggisser et al., 2010). Regarding the mowing time, significant differences could be expected between traditional and ecological viticulture, both present in the study area.

The present study focuses on the comparison between semi-natural grassland patches and flower strips in vineyards. We recorded the floristic diversity, vegetation structure and flower cover (as a cue for pollen respectively nectar availability). Parallel, we analyze the quantities and species composition of flower-visiting insects with special focus on wild bees. Following research questions can be worded:

i. How far does the flower cover correlate with diversity and quantity of flower visiting insects?

ii. Are there significant differences in composition of insect communities in general and bee communities in particular between semi-natural grasslands and flower strips?

iii. Are there significant differences between flower strips within traditional and ecological viticulture regarding the pollinator communities?

Material and Methods

Study areas

The present study was carried out at two low mountains on the outskirts of the city of Vienna (Austria): Bisamberg north of the Danube (N 48° 18` E 16° 22`, 358 m a. s. l.) and Leopoldsberg/Nussberg south (N 48° 16` E 16 21`, 425 m a. s. l.). These mountains belong to the most NE-part of Vienna Forest and build together the so called "Vienna Gate" of the Danube valley. The south-exposed slopes of both mountains are covered by semi-dry deciduous forests (downy oak forests), different types of semi-dry calcareous grasslands (Mesobromion) and vineyards. We selected ten plots per area (Bisamberg – five grasslands and five vineyard flower strips; Leopoldsberg/Nussberg – three grasslands and seven vineyard flower strips). On Bisamberg all vineyard flower strips and three of five grassland plots were situated within the research farm "Götzhof" (Federal Department of Viti- and Pomiculture), where ecological agricultural methods are tested. The vineyards and associated flower strips on Nussberg are managed in a traditional way. The study areas are about 5 km away from each other and within the area all study plots were situated within the circle of about 1200 m diameter.

The study plots were of different shape dependent on the landscape - from 10 x 10 m squares in grassland to 1.5 x 66.6 m strips between vine rows, but of the same size of 100 m². The current management and the composition of seed mixtures for flower strips are listed in Table 1.

Vegetation and insect surveys

Each study plot was monitored six times from May to July 2015 in a two week interval. The monitoring included an observation of flower-visiting insects performed by one person with a sampling time of 15 minutes by patrolling the plot (linear or zigzag dependent on plot configuration) and capturing the insects with help of an entomological hand-net. All captured insects were immediately counted. Individuals, which could not be easily identified in the field, were killed with ethyl acetate and preserved for further identification. The focus insect group of bees (Apiformes) and some easily recognizable Coleoptera and Macrolepidoptera were determined down to species level, while at some groups (e.g. Diptera) we had to deal with morphospecies. Bee species were categorized according to their food and nesting preferences following Scheuchl and Willner (2016). Nomenclature of bee species follows Gusenleitner et al. (2012). Insect monitoring took place in the daytime and only in good weather (temperature above 15°C, no precipitation). Subsequent to the insect record a vegetation relevée (scale based on cover percentages of single species) after Londo (Londo, 1976) was performed for the study plot, while besides cover of plant species their contribution to flower cover was estimated. Entomophilous plants with currently open blossoms were seen as relevant

Table 1. Description of the study sites at Bisamberg (B1-B10) and at Leopoldsberg/Nussberg (L1-L10), habitat type (flower strip/grassland), plot shape (length x width; m), vegetation/land use, coordinates and exposition. All plots were of the same size of 100 m².

	habitat type	plot size (m)	vegetation/land use	coordinates	slope angle (°), exposition
Bisamberg					
B1	flower strip	5 x 20	spontaneous re-vegetation, *Lepidium draba*- dominant cover	N48°18´47.7´´ E16°22´18.6´´	20 S
B2	flower strip	1.5 x 66.6	3-component-seed mixture*	N48°18´45.7´´ E16°22´24.6´´	10 S
B3	grassland	10 x 10	mown in summer	N48°18´45.2´´ E16°22´27.8´´	8 S
B4	flower strip	1.5 x 66.6	3-component-seed mixture*	N48°18´45.2´´ E16°22´29.6´´	8 S
B5	flower strip	1.5 x 66.6	seed mixture "Rebenfit"**	N48°18´39.0´´ E16°22´28.1´´	8 - 15 S
B6	grassland	10 x 10	mown in summer	N48°18´39.5´´ E16°22´26.5´´	5 S
B7	grassland	10 x 10	mown in summer	N48°18´39.9´´ E16°22´20.7´´	6 S
B8	flower strip	1.5 x 66.6	seed mixture "Rebenfit"**	N48°18´39.7´´ E16°22´18.4´´	6 S
B9	grassland	10 x 10	mown in autumn/abandoned	N48°18´45.8´´ E16°21´46.1´´	2 - 3 S
B10	grassland	10 x 10	mown in autumn/abandoned	N48°18´46.9´´ E16°21´41.2´´	15 - 18 S
Leopoldsberg/Nussberg					
L1	grassland	10 x 10	mown in autumn/abandoned	N48°16´29.4´´ E16°20´34.2´´	12 E
L2	grassland	10 x 10	mown in autumn/abandoned	N48°16´29.6´´ E16°20´31.4´´	8 E
L3	grassland	10 x 10	mown in autumn/abandoned, *Orlaya grandiflora*-dominant cover	N48°16´35.1´´ E16°20´43.4´´	40 S
L4	flower strip	1 x 100	sown *Trifolium incarnatum, Phacelia tanacetifolia, Fagopyrum esculentum, Sinapis alba, Raphanus sativus* and *Vicia sativa*	N48°16´07.9´´ E16°20´40.9´´	4 - 10 NE
L5	flower strip	10 x 10	sown *Trifolium incarnatum, Camelina sativa, Centaurea cyanus, Trifolium repens, Medicago sativa, Medicago lupulina* and *Plantago lanceolata*	N48°16´01.9´´ E16°20´54.6´´	1 - 2 NE
L6	flower strip	1.5 x 66.6	sown *Sinapis alba, Raphanus sativus* subsp. *oleiferus, Phacelia tanacetifolia, Melilotus officinalis, Vicia sativa, Vicia pannonica, Calendula officinalis* and *Malva sylvestris*	N48°16´00.6´´ E16°20´57.5´´	0 - 2 S
L7	flower strip	1 x 100	*sown Melilotus officinalis, Sinapis alba, Raphanus sativus subsp. oleiferus, Trifolium incarnatum, Vicia pannonica, Malva sylvestris, Phacelia tanacetifolia, Trifolium pratense, Trifolium alexandrinum* and *Cichorium intybus*.	N48°15´58.8´´ E16°21´03.7´´	4 - 10 S
L8	flower strip	10 x 10	sown *Medicago sativa*	N48°15´56.4´´ E16°21´10.9´´	8 - 10 S
L9	flower strip	1.5 x 66.6	sown *Trifolium repens*	N48°15´47.5´´ E16°21´22.0´´	2 - 12 S
L10	flower strip	1.5 x 66.6	sown *Medicago sativa*	N48°15´48.4´´ E16°21´26.6´´	2 - 12 S

3-component-seed mixture includes *Phacelia tanacetifolia, Fagopyrum esculentum* and *Trifolium incarnatum.*
** seed mixture "Rebenfit", includes *Camelina sativa, Trifolium incarnatum, Trifolium repens, Medicago lupulina, Plantago lanceolata* and *Centaurea cyanus.*

for flower-visiting insects. Some species, normally seen as wind-pollinated (e.g. *Plantago lanceolata* (L.)) were counted to the flower cover as well due to the potential importance of their pollen as food for insects (e.g. Sharma et al., 1993). Determination and nomenclature of plant species was according to Fischer et al. (2008).

We studied the relationship between species richness respectively quantities of insects and characteristic of study plots (incl. flower cover of different plant groups) applying linear regression and analysis of variances (ANOVA). A Repeated Measurement ANOVA was calculated to study the effect of observation time. Additionally, factor "time" was included in a Three-Way ANOVA together with the factors "area" and "habitat" (grassland vs. flower strips) to study the interactions between them . A canonical correspondence analysis (CCA) was applied to put the entire species composition of bee communities in relation to land use and flower aspect. The statistical analyses were performed using the software package R 2.15.2 (R Development Core Team, 2015). Multivariate analyses were performed using CANOCO 5 (Smilauer & Leps, 2014).

Results

Vegetation and flower cover

Semi-natural grasslands on both study areas included 28 to 48 species of flowering plants per 100 m² (without Poaceae). The plant species diversity on the flower strips was significantly lower, not above 20 species, in most cases about 10. The estimated flower cover, however, reached similar values for both grassland and flower strips and in some cases was even higher on the last mentioned (Table 2, Fig 1). Most significant for the flower cover of strips was the contribution of sown species such as *Phacelia tanacetifolia* Benth., *Trifolium incarnatum* L. or *Sinapis alba* L., but some spontaneously established ruderal species such as *Lepidium draba* L. could locally reach a high flower density. The flower cover of grassland plots was mainly polydominant, but strong contribution of one single species in a particular point of time (e.g. *Orlaya grandiflora* (L.) Hoffm. on one of the plots on Leopoldsberg) was also observed.

The temporal variation of the flower cover was especially high at flower strips (Table 2, Fig 1). Generally, the flower cover tended to reduce during the recording period from May to July. Flower strips between vine rows were mown usually once (ecologically managed flower strips on Bisamberg) or twice (traditionally used flower strips on Nussberg) during the observation period. In some cases vegetation could rapidly recover from these effects and developed high flower cover for the second time, but there was a significant time span, where the flower offer for pollinators was lowered. Grassland patches were usually mown in late summer (after the observation period was finished) or remain unmown.

Table 2. Differences of plant species diversity, flower cover, flower visiting insects and insect groups between the investigated locations (Bisamberg, Leopoldsberg/Nussberg) and habitats (flower strip and grassland) as well as their interactions. Three-way full factorial ANOVA. Values of Fisher-distribution (F-value) are shown. Significant effects are highlighted and marked as follows: * p<0.05, ** p<0.01 and *** p< 0.001. ns – not significant.

dependent	Area	Time	Treatment (grassland vs. flower strips	Area x Time	Area x Treatment	Time x Treatment	Area x Time x Treatment
No. of plant species	3.6 ns	1.78 ns	41.71***	0.1 ns	23.81***	0.07 ns	0.15 ns
Sum flower cover	0.01 ns	6.07 ***	2.63 ns	2.77*	6.61*	1.61 ns	4.18**
Flower cover Brassicaceae	0.01 ns	5.78***	7.3**	0.84 ns	0.12 ns	2.14 ns	1.29 ns
Flower cover Asteraceae	1.16 ns	0.96 ns	21.54***	0.69 ns	11.66***	1.02 ns	2.44*
Flower cover Apiaceae	2.23 ns	0.42 ns	8.28 **	1.32 ns	3.69 ns	0.82 ns	1.98 ns
Flower cover Fabaceae	7.9**	1.19 ns	1.29 ns	0.87 ns	4.18*	0.22 ns	0.45 ns
No. of insect species	1.64 ns	1.3 ns	6.52*	1.27 ns	28.84***	1.31 ns	2.15 ns
No. of insect ind.	8.17**	2.62*	4.07*	3.39**	12.04***	2.49*	3.66**
Hymenoptera species	0.91 ns	0.24 ns	0.12 ns	1.41 ns	6.65*	1.37 ns	1.46 ns
Hymenoptera ind.	6.74*	1.86 ns	5.68*	3.05*	4.78*	2.37*	2.18 ns
Coleoptera species	4.33*	1.44 ns	4.98*	1.61 ns	20.44***	1.27 ns	1.49 ns
Coleoptera ind.	4.09*	1.59 ns	0.05 ns	1.27 ns	12.76***	0.86 ns	2.29 ns
Lepidoptera species	0.36 ns	2.07 ns	35.08***	2.38*	20.27***	2.72*	1.17 ns
Lepidoptera ind.	2.4 ns	1.81 ns	31.38***	1.74 ns	20.11**	2.59*	2.14 ns
Diptera species	2.89 ns	3.89**	0.12 ns	2.38*	22.65***	2.95*	3.08*
Diptera ind.	0.01 ns	2.56*	0.44 ns	3.02*	23.08***	3.65**	5.92***

Flower visiting insects in general

During the study entirely 201 (morpho-) species of flower-visiting insects were recorded. The most species-rich insect group was Hymenoptera with 62 species (incl. 41 species of Apiformes), followed by Diptera (48), Lepidoptera (45), Coleoptera (31 species), Hemiptera (14) and Neuroptera (1). The number of insect species per record was similar between different sites. The only slight significant differences could be seen between land use forms (Table 2). Semi-natural grassland possessed higher insect diversity, than flower strips. Individual numbers (quantities) of insects recorded on study plots differ both between areas and land use forms and fluctuate strongly in time (repeated measurements ANOVA, $F = 2.97$ $p < 0.05$), while these fluctuations have different rhythms in different treatments (Table 2). The quantities of insects were significantly correlated with the flower cover (Ad. $R^2 = 0.325$, $F = 56.92$, $p < 0.001$), but not with the diversity of plant species (Ad. $R^2 = -0.005$, $F = 0.35$, n.s.).

Bee communities

We identified entirely 41 bee species (Apiformes) during the study, 14 of them occurring only in grassland, 19 only in flower strips within vineyards and 8 in both habitat types (Table 3). Number of bee species was significantly correlated to the plant species diversity per plot (Ad. $R^2 = 0.134$, $F = 19.42$, $p < 0.001$), while number of individuals was clearly dependent on the entire flower cover (Ad. $R^2 = 0.261$, $F = 43.00$, $p < 0.001$). Most numerous were *Apis mellifera* (L.), *Bombus lucorum* (L.) / *Bombus terrestris* (L.) and *Bombus lapidarius* (L.). Honey bees and large earth bumblebees reached the highest individual numbers on *Phacelia*-dominated flower strips during its flowering time. Regarding their pollen specification, the majority of detected bee species can be considered as polylectic, but there are also some specialists / oligolectic species. As specialists on flower strips species using Brassicaceae (*Andrena agilissima* (Scop.) and *Andrena floricola* (Ev.)), Apiaceae (*Andrena nitidiuscula*

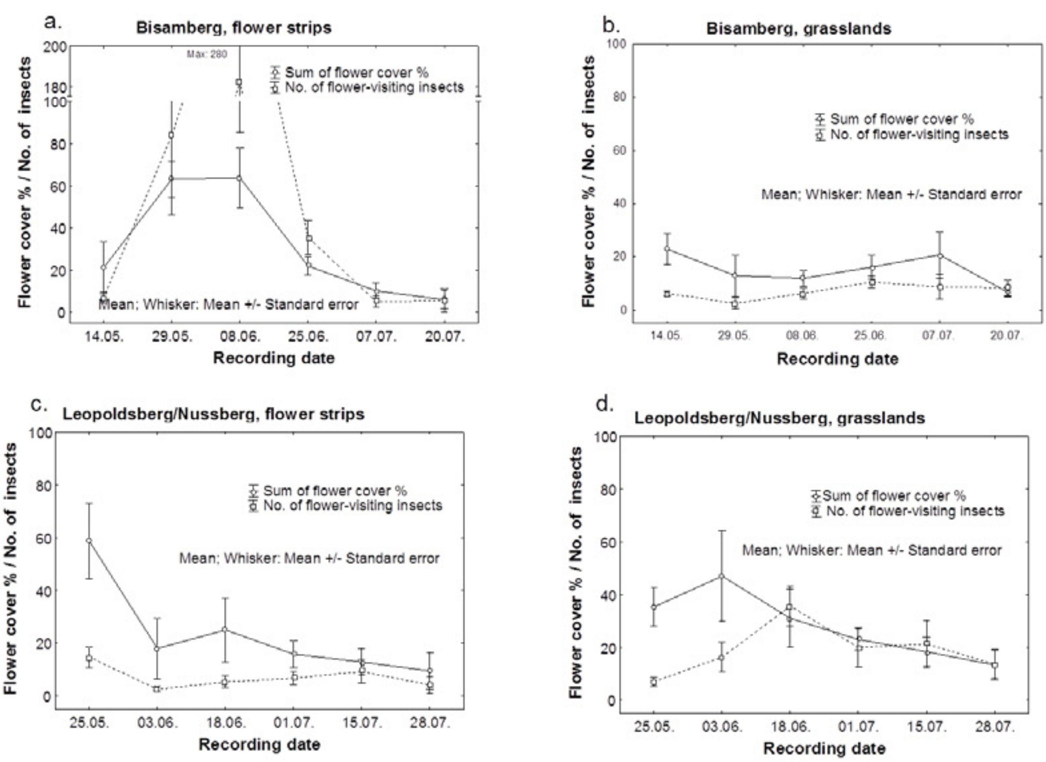

Fig 1. Temporal dynamic of total flower cover in percent in relation to the total number of flower visiting insects, separated by location (Bisamberg vs. Leopoldsberg/Nussberg) and habitat type (flower strip/ grassland). Year of recording: 2015. Mean and mean +/- standard error is shown.

(Schenck)), Asteraceae (*Colletes similis* (Schenck)), Fabaceae (*Eucera nigrescens* (Pérez) and *Melitta leporina* (Panz.)) as well as *Convolvulus*-Species (*Systropha curvicornis* (Scop.)) could be detected. At grassland patches there were mainly specialists feeding on Asteracea (*Heriades crenulatus* (Nyl.), *Hylaeus nigritus* (Fab.), *Megachile pilicrus* (Mor.) and *Osmia spinulosa* (Kir.)) and on Ranunculaceae (*Chelostoma florisomne* (L.)).

There were also some differences in the bee species composition between habitats regarding their nesting behavior. The most common category were terricolous (ground nesting) species, wide spread on all sites. In contrast, cavity nesting could be mainly found on grassland sites (9 species) and only two of them on flower strips. All three species nesting in snail shells were only found in semi-natural grassland, among them the rare and in Austria endangered species *Anthidium septemdentatum* (Latr.).

Table 3. Distribution of bee species (Apoidea) between the habitats (flower strips in vineyards vs. grassland), pollen source and nesting behavior after Scheuchl & Willner, 2016 (p - cleptoparasite, h - cavity breeder, t - ground-nesting, t/h - ground-nesting and cavity breeder, hs - breeding in snail shells).

	flower strips	grassland	Pollen source	Nesting behavior
Andrena agilissima (Scopoli, 1770)	x		Brassicaceae	t
Andrena chrysosceles (Kirby, 1802)		x	polylectic	t
Andrena floricola Eversmann, 1852	x		Brassicaceae	t
Andrena haemorrhoa (Fabricius, 1781)	x		polylectic	t
Andrena minutula (Kirby, 1802)	x		polylectic	t
Andrena minutuloides Perkins, 1914	x		polylectic	t
Andrena nitidiuscula Schenck, 1853	x		Apiaceae	t
Anthidium septemdentatum Latreille, 1809		x	polylectic	hs
Apis mellifera Linnaeus, 1758	x	x	polylectic	
Bombus hortorum (Linnaeus, 1761)	x		polylectic	t/h
Bombus hypnonum (Linnaeus, 1758)	x		polylectic	t/h
Bombus lapidarius (Linnaeus, 1758)	x	x	polylectic	t/h
Bombus lucorum/Bombus terrestris	x		polylectic	t/h
Bombus pascuorum (Scopoli, 1763)	x		polylectic	t/h
Chelostoma florisomne (Linnaeus, 1758)		x	Ranunculus	h
Colletes similis Schenck, 1853	x		Asteraceae	t
Eucera nigrescens Pérez, 1879	x	x	Fabaceae	t
Halictus quadricinctus (Fabricius, 1776)	x	x	polylectic	t
Halictus rubicundus (Christ, 1791)		x	polylectic	t
Halictus sexcinctus (Fabricius, 1775)		x	polylectic	t
Halictus simplex Blüthgen, 1923	x	x	polylectic	t
Halictus tumulorum (Linnaeus, 1758)	x		polylectic	t
Heriades crenulatus Nylander, 1856		x	Asteraceae	h
Hylaeus communis Nylander, 1852		x	polylectic	h
Hylaeus gredleri Förster, 1871		x	polylectic	h
Hylaeus nigritus (Fabricius, 1798)		x	Asteraceae	h
Lasioglossum malachurum (Kirby, 1802)		x	polylectic	t
Lasioglossum marginatum (Brullé, 1832)	x	x	polylectic	t
Lasioglossum nigripes (Lepeletier, 1841)	x		polylectic	t
Lasioglossum pauxillum (Schenck, 1853)	x	x	polylectic	t
Lasioglossum politum (Schenck, 1853)		x	polylectic	t
Lasioglossum leucozonium (Schrank, 1781)	x		polylectic	t
Megachile pilicrus Morawitz, 1877		x	Asteraceae	h
Megachile rotundata (Fabricius, 1787)	x		polylectic	h
Melitta leporina (Panzer, 1799)	x		Fabaceae	t
Nomada succincta Panzer, 1798	x		p	p
Osmia bicolor (Schrank, 1781)		x	polylectic	hs
Osmia spinulosa (Kirby, 1802)		x	Asteraceae	hs
Sphecodes gibbus (Linnaeus, 1758)	x	x	p	p
Systropha curvicornis (Scopoli, 1770)	x		Convolvulus spp.	t
Xylocopa violacea (Linnaeus, 1758)	x		polylectic	h

The species composition and quantity of bee communities have a good explanatory value between the studied habitats (CCA, Aj. expl. variation was 39.26 %, Axis 1 – 18.09 %, Axis 2 – 16.68 %, Pseudo-F on all axes =1.8, p = 0.013). In the ordination diagram bee communities clustered mainly in three groups corresponding to semi-natural grasslands (upper left part), flower strips in traditionally managed vineyards (right-hand part) and ecologically managed vineyards together with regularly mown grasslands (downer left part; Fig 2).

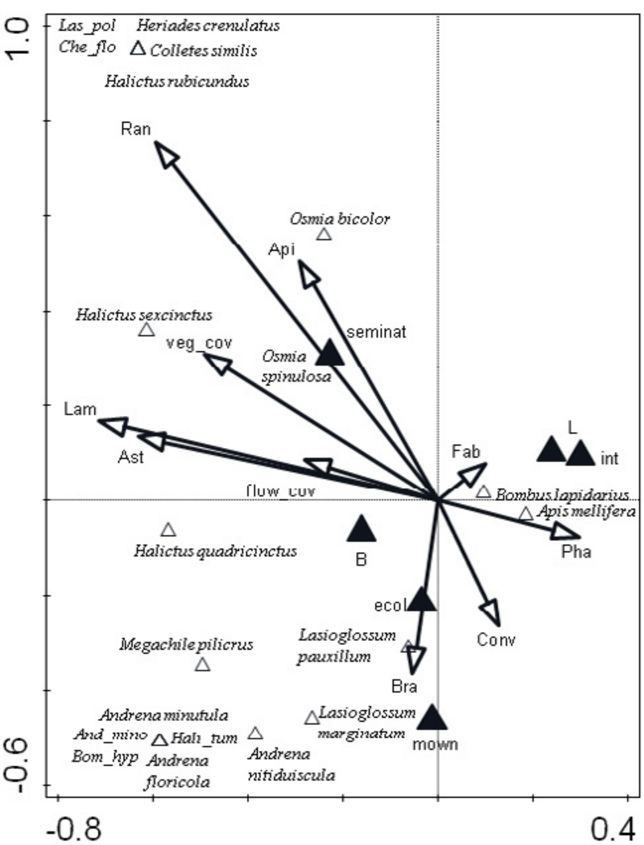

Fig 2. Constrained ordination (CCA) of studied plots (without consideration of time dynamics). Vegetation cover (veg_cov), total flower cover (flo_cov) as well as flower cover of single plant groups: Ranunculaceae (Ran), Lamiaceae (Lam), Asteraceae (Ast), Apiaceae (Api), Fabaceae (Fab), *Convolvulus* (Conv) & *Phacelia* (Pha) were plotted as passive variables. B - location Bisamberg, L – location Leopoldsberg/Nussberg, seminat – semi-natural grassland, mown – intensively used grassland, ecol – flower strips in organic vineyards, int - flower strips in traditional vineyards. Bee species with the highest explanatory values are shown (see Table 3). Following species names are shortened: *And_mino - Andrena minutuloides, Bom_hyp - Bombus hypnonum, Che_flo - Chelostoma florisomne, Hali_tum - Halictus tumulorum, Las_pol - Lasioglossum politum.*

Discussion

As expected, the flower cover was the most significant predictor for quantities of insects in general and for the most common / generalist flower visitors in particular (Potts et al., 2003; Holland et al., 2015). Fluctuations of flower cover caused immediately changes at insect numbers.

Indeed, our study showed that semi-natural Pannonian grasslands remain a higher diversity and higher quality habitat for insects, especially bee species, in comparison to farmland. Even under pollinator-friendly conditions flower strips include a narrow selection of nectar- and pollen-offering plant species, not including those relevant for foraging specialists (see Wood et al., 2015). In our case flower strip sown mixtures contained no Ranunculaceae and only a little amount of Asteraceae-species, while these plant families were strongly represented in grassland patches. Also wild growing Apiaceae (*O. grandiflora*) and Brassicaceae (*Lepidium draba*) dominated locally some grassland patches and were important attractors for various insect species. Seed mixtures showed higher cover of Fabaceae (especially *T. incarnatum, Medicago sativa* (L.)) and *P. tanacetifolia,* a plant not present in grassland. These species together with Brassicaceae (*S. alba*) led flower strips within vineyards to provide very high values of flower cover. The entire number of insects, mainly generalists foraging on these species, was comparable or even higher, than on grasslands, especially mown (traditionally used) ones (see also Aviron et al., 2011). Generally, due to high quantities of flower visiting insects flower strips should be able to provide ecosystem (pollination) services for the surrounding landscape (Korpela et al., 2013).

Further differences between grasslands and flower strips for bee species were manifested regarding the structure of microhabitats. This include the effects of nesting behavior (availability of cavity including snail shells) or in general the flower-richness of the surrounding and landscape heterogeneity (Rundlöf et al., 2008; Spiesman, 2017). Cultivation of vine rows and associated flower strips destroy small cavities, necessary as nesting habitats for bees. Semi-natural grasslands for their part are more suitable habitats for small snails, than flower strips. Bee species dependent on these structures occur mainly or solely at undisturbed dry grasslands.

Differences between flower strips in traditional and organic vineyards are manifested in significant effects of area x treatment interaction, as vineyards of Bisamberg were organic ones and of Nussberg/Leopoldsberg the traditional ones. Flower cover of the strips differed only slightly between the two agricultural forms. But temporal dynamics (due to 2x cut of intensively used strips vs. 1x cut in ecological farming) differed more clearly. Similar to Holzschuh et al. (2007) we also found that the differences in insect (and especially bee) diversities and quantities could be to a significant part explained by the differences in flower cover.

Remarkable are the similarities between moderately used grasslands and flower strips in organic managed vineyards (compare Holzschuh et al., 2010). Besides the similarities in management (1x mowing in mid-summer) avoidance of pesticide use could be a good explanation for the high species diversity there compared to traditional farming (e.g. Thompson, 2001, 2003). Attraction of wild bee species and further pollinators (e.g. hoverflies) is an important improvement of pollination services of flower strips for the neighbored crops (Campbell et al., 2017).

Conclusions

Flower strips in vineyards are able to provide food for high quantities of flower-visiting insects, comparable to semi-natural grasslands of the surrounding. Especially strips within ecologically managed vineyards are comparable to moderately used (mown) grassland patches. The diversity of insect and explicitly of bee species was however higher at grassland sites due to food and nesting specialists, dependent on them. The development of ecologically managed flower strips can thus provide the important ecosystem service of pollination in the landscape, but protection of grassland patches is either crucial for the preservation of biodiversity.

Acknowledgments

We would like to thank Dr. Reinhard Eder and Stefan Lassl from the research farm "Götzhof" for their help and important information. Dr. Kati Vogt and two anonymous reviewers helped us with their remarks to improve the manuscript. The research was supported by the University Foundation of the City of Vienna (Hochschuljubiläumsstiftung der Stadt Wien).

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