Attractiveness of flowering plants for natural enemies

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Abstract

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The set of 7 flowering plant species (*Anethum graveolens, Calendula officinalis, Centaurea cyanus, Fagopyrum esculentum, Foeniculum vulgar*e, *Tagetes patula* and *Vicia faba*) was compared for their attractiveness to natural enemies such as ladybeetles (Coccinellidae), hoverflies (Syrphidae), ichneumon wasps (Ichneumonidae) and predatory bugs (*Orius* spp.) during the years 2008–2010. The trial was held in an organic open field located at the Faculty of Horticulture of Mendel University in Brno, Lednice, Czech Republic. The software Canoco (RDA analysis) was used in order to see the relations between plant and insect communities. Flowering plants *A. graveolens, C. cyanus, C. officinalis, F. vulgare* and *F. esculentum* were found to be the most attractive for the evaluated beneficial insects. The most abundant beneficial insects were hoverflies (56_{2008}, 154_{2009}, 1324_{2010}) and ladybeetles (65_{2008}, 116_{2009}, 511_{2010}) followed by predatory bugs (14_{2008}, 47_{2009}, 138_{2010}) and ichneumon wasps (20_{2008}, 14_{2009}, 82_{2010}).

Keywords: flowers; beneficial insects; visiting; biodiversity

The highly intensive agricultural production systems lead to the simplification of agricultural landscapes, and the subsequent removal of non-crop habitats causes a decline in biodiversity. The agricultural intensification creates unsuitable conditions for natural enemies (Bianchi et al. 2006; Pfiffner et al. 2006). Many studies showed that natural enemy populations are higher and pest pressure lower in complex landscapes with a high proportion of non-crop habitats (Alomar et al. 2006; Bianchi et al. 2006). The use of plants to provide nectar and pollen resources to natural enemies is increasingly common (Ambrosino et al. 2006; Fiedler, Landis 2007).

Many studies as mentioned by Ambrosino et al. (2006) showed that a wide range of insect predators and parasitoid families use a floral pollen and nectar. Therefore plants providing these resources can support agroecosystems to conserve and enhance these natural enemies. According to Pfiffner (2006), such an infrastructure should ideally offer suitable food for adult natural enemies, an alternative prey or host organism, and shelter from adverse conditions. However, some authors pointed out that the use of flowering strips might not always be a successful tool used in the biological control of crop pests (Winkler et al. 2006). The ability of natural enemies to utilize floral resource subsidies

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is dependent on a wide range of factors, including flower morphology, colour, odour or the timing of nectar production (Heimpel, Jerwis 2005). It is important to choose the optimal set of plant family instead of the greatest species diversity (Roy et al. 2008). Winkler (2005) suggests that, plant species which maximise the benefit to the natural enemies and have no, or only weak, benefits for the pest should be selected.

A wide knowledge of insect-flower relations is therefore needed to be able to determine which plants are going to be suitable. In order to find suitable combinations of plants for flowering edges, van Rijn et al. (2006) suggests firstly to identify which natural enemies are effective against a specific pest, and then, provide them with suitable food. Providing floral species must be attractive to these natural enemies. Of course, flowering plant species classified as beneficial for potential insect pests should be discarded.

The goal of this work was to test the natural enemy preference to plant species by monitoring the occurrence of insect visitation over time. The attractiveness of selected flowering plant species (*A. graveolens, C. officinalis, C. cyanus, F. esculentum, F. vulgar*e, *T. patula* and *V. faba*) for the natural enemies (Coccinellidae, Syrphidae, Ichneumonidae, and *Orius* spp.) was examined in this experiment. We were also searching for the optimal horticultural and agricultural practical use of flowering plants for enhancing the natural enemy populations.

MATERIAL AND METHODS

The small-scale field trial was held in an organic open field located at the Faculty of Horticulture of Mendel University in Brno, Lednice, Czech Republic between years 2008–2010. The visits of plants made by the selected natural enemies were quantified by regular visual observation.

All fields were managed with no chemical inputs and were hand weeded. The experimental field was surrounded by a field of alfalfa. Due to the dry climate the field was irrigated in the first 2 years. Coccinellidae, Syrphidae, Ichneumonidae and *Orius* spp. were counted among the present natural enemies. Many species from these groups are native in the Czech agroecosystems and serve as important natural enemies (Rod et al. 2005).

The impact of the natural enemies on the pest populations was not evaluated in this trial. Some differences in insect and/or plant species, environmental context and the possible interaction, which these factors can have with habitat preferences of natural enemies, were assumed by Branquart and Hemptinne (2000). Different design was chosen for each year to be able to confirm that certain natural enemies attract specific floral species in this system which is influenced by various factors. Monitoring started in week 26, in 2011 it was in week 22.

Year 2008. The flowering plant strips were sown on May 27, 2008. The flowering strips were designed with three replications for the area of 13.5 m^2 (1.5 m wide, 9 m long). The distance between replications was 7 m. The following flower species for the mixture were chosen: *A. graveolens, C. cyanus, C. officinalis, T. patula* and *V. faba*. Chosen flowering species were sown randomly in mixture. Two plants from each species in every replication were randomly selected and marked with a stake (30 plants in total). Natural enemy visits to the plants were recorded by visual observation of each marked plant simultaneously (approx. 1 min for 1 plant). Observations were performed once a week from July to September always between 9 and 11 a.m. when irrigation was not taking place. All the observed natural enemies were counted together as visiting and feeding the plant or resting on it.

Year 2009. First year design (plant sown as a mixture) was found not to be suitable from practical point of view due to the high level of weed infestation. Farmers would not be willing to spend a lot of time on hand weeding so for the next season we choose sowing in rows which allows using the weeder. This makes keeping of weeds under control, which is necessary in the early period.

The flowering plant strips were sown on May 29, 2009. The distance between the replications, the area of strip, the species composition of flowering strip and the observation period was the same as in 2008. On the contrary, the plant species were sown in rows. Every replication contains 4 separated rows (approx. 2 m long) of each plant species. *Vicia faba* was sown randomly within all rows. Natural enemy visits to the plants were recorded by visual observation of each of the rows simultaneously (approx. 2 min for 1 row of plants). In total, one plant species in one replication was observed 4 times.

Year 2010. The flowering plant strips were sown on April 21, 2010. During the first 2 years *V. faba* and *T. patula* were evaluated as being not very visited by the observed natural enemies, and therefore were discarded. *F. vulgare* and *F. esculentum* as the potential sources for natural enemies (Boller et al. 2004; Fiedler, Landis 2007) were added to the group of species. Each of these 5 plant species was sown in a 4 m^2 (2 m wide, 2 m long) plot with 5 replications in Latin square design. The number of visits to flowers observed during 3 min in the area of each plot was recorded. More time was needed due to the bigger area which was observed. The field was not irrigated because of the sufficient amount of precipitation.

As described by Altieri and Nicholls (2004), the insect searching can be influenced by many factors such as plant spacing, chemical or visual stimuli. A host plant is also found by the insect thanks to the olfactory mechanism. In plant mixture the disruption of insect finding behaviour can occur (masking effect). It was also stated that monocultures make plants more apparent to insect. Therefore the question is if the same flower-insect relation will be expressed in 2010 year design.

The data were collected and compared within each year. The software for multivariate analysis of ecological data (Canoco v.4.5.4, Biometris – Plant Research International, Wageningen, The Netherlands) was used for the analysis. The Redundancy analysis (RDA) (Ter Braak, Šmilauer 1998) was chosen as the statistical method.

RESULTS

Total amounts of observed species in all flowering plants are given in Table 1. The highest appearance of natural enemy species is highlighted for each flower species and year. The program Canoco for ecological data modelling was used for different approach of evaluation in order to see the relations between the plant and insect communities.

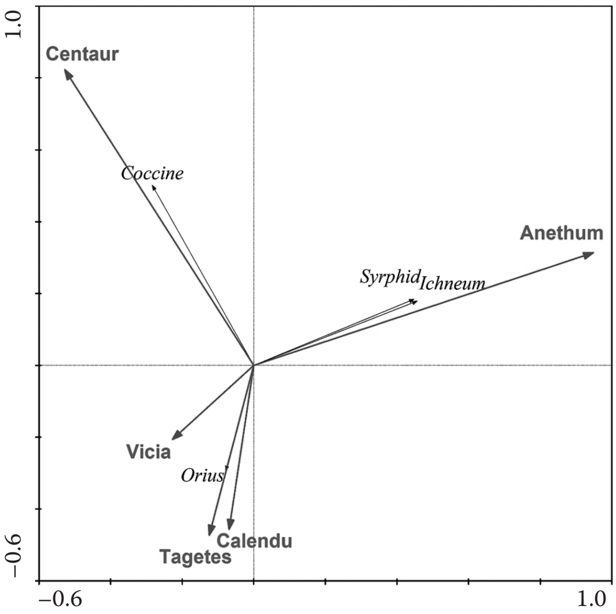

Fig. 1. RDA analysis for year 2008 (eigenvalues – 0.156, F – 8.336, P – 0.006**)

Year 2008. The abundance of natural enemies (Fig. 1) was performed on selected flowering plants. There was a strong relation between Coccinellidae and *C. cyanus*. Syrphidae and Ichneumonidae preferred *A. graveolens*. The preference of *Orius* spp. was relatively modest, probably due to their low frequency during the observation. They were recorded only on *C. officinalis*.

The following data (Tables 2–4) shows the flowering period of selected plants and the total number of observed natural enemies for each week. Main flowering period is defined as the period when at least one plant has more than 1/3 of its possible flowers open.

Table 1. Total number of insects for every year of the experiment

Flower species	Coccinellidae			Ichneumonidae			*Orius* spp.			Syrphidae		
	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010
Anethum graveolens	6	5	94	**16**	**12**	15	0	0	0	**49**	**127**	107
Calendula officinalis	1	0	15	2	0	16	**14**	**47**	**138**	3	11	134
Centaurea cyanus	**48**	**107**	162	2	2	10	0	0	0	4	3	158
Tagetes patula	0	0	×	0	0	×	0	0	×	0	10	×
Vicia faba	10	4	×	0	0	×	0	0	×	0	3	×
Fagopyrum esculentum	×	×	41	×	×	0	×	×	0	×	×	**719**
Foeniculum vulgare	×	×	**199**	×	×	**41**	×	×	0	×	×	206

× – not observed in this period; bold numbers – flower species with highest number of observed insects

Table 2. Insect occurrence and flowering period in 2008

Species	Insect/Week	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Anethum graveolens	Syrphidae				1	2	17	22	4	3						
	Ichneumonidae						5	6	4	1						
	Coccinellidae				2	1		2	1							
	Orius spp.															
	main flowering period*					♣	♣	♣	♣	♣	♣	♣	♣			
Calendula officinalis	Syrphidae						1	1	1							
	Ichneumonidae								2							
	Coccinellidae					1										
	Orius spp.			1	2		1	3	3	4						
	main flowering period*			♣	♣	♣	♣	♣	♣	♣	♣	♣	♣	♣	♣	
Centaurea cyanus	Syrphidae				1	1		2								
	Ichneumonidae								2							
	Coccinellidae		1	8	12	6	16	4	1							
	Orius spp.															
	main flowering period*			♣	♣	♣	♣	♣	♣	♣	♣	♣	♣	♣	♣	♣
Tagetes patula	Syrphidae															
	Ichneumonidae															
	Coccinellidae															
	Orius spp.															
	main flowering period*				♣	♣	♣	♣	♣	♣	♣	♣	♣	♣	♣	♣
Vicia faba	Syrphidae															
	Ichneumonidae															
	Coccinellidae		5	3	1	1										
	Orius spp.															
	main flowering period*	♣	♣	♣	♣	♣	♣	♣	♣							

*1/3 of flowers opened

Year 2009. Compared to the previous year, in 2009 (Fig. 2) the groups of plants were observed (about 2-meter long row of plants of the same species). Such change of design resulted in a greater amount of data obtained. Coccinellidae were found on the *C. cyanus*, and Syrphidae and Ichneumonidae on *A. graveolens*. *Orius* spp. were again recorded only in a small number on *C. officinalis*.

Year 2010. The 2010 group of plants were observed as a square parcel of monocultures, resulting in a large amount of data. Compared to the previous two years, we added *F. esculentum* and *F. vulgare*, while *T. patula* and *V. faba* were discarded. Even if those species were recommended, we didn't mark the significant relation with the observed insects. As in previous years, Coccinellidae were found on *C. cyanus*, and also preferred *F. vulgare* and *A. graveolens*. In this year, Syrphidae showed strong preference for *F. esculentum* (Fig. 3), however they were seen in all observed flowering species. *Orius* spp. showed a strong preference for *C. officinalis*. Ichneumonidae strongly preferred *F. vulgare* but were also present on *C. officinalis*, *C. cyanus* and *A. graveolens*.

We can see from Table 1 that in year 2010 Coccinellidae markedly visited also *A. graveolens* as well as Syrphidae were seen more on *C. cyanus* and *C. officinalis* which confirms the previous assumption.

DISCUSSION

The goal of this work was to test natural enemy preference to plant species by monitoring the occurrence of insect visitation over time. Many of the plant species in this trial have already been identified as being potentially suitable sources of pollen or nectar for beneficial insects. Our interest was particularly focused on Coccinellidae, Syrphidae, Ichneumonidae

Table 3. Insect occurrence and flowering period in 2009

Species	Insect/Week	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Anethum graveolens	Syrphidae							40	49	22	9	5	2			
	Ichneumonidae							9	2		1					
	Coccinellidae							2	3							
	Orius spp.															
	main flowering period*							♣	♣	♣	♣	♣	♣	♣		
Calendula officinalis	Syrphidae						2	3	1	2	1		2			
	Ichneumonidae															
	Coccinellidae															
	Orius spp.							2	39	5	1					
	main flowering period*					♣	♣	♣	♣	♣	♣	♣	♣	♣	♣	♣
Centaurea cyanus	Syrphidae					2	1									
	Ichneumonidae							2								
	Coccinellidae			5	11	7	38	25	11	9	1					
	Orius spp.															
	main flowering period*						♣	♣	♣	♣	♣	♣	♣	♣	♣	♣
Tagetes patula	Syrphidae						1	1		2	3	3				
	Ichneumonidae															
	Coccinellidae															
	Orius spp.															
	main flowering period*				♣	♣	♣	♣	♣	♣	♣	♣	♣	♣	♣	♣
Vicia faba	Syrphidae					3										
	Ichneumonidae															
	Coccinellidae			1	2	1										
	Orius spp.															
	main flowering period*			♣	♣	♣	♣	♣	♣							

*1/3 of flowers opened

and *Orius* spp. For example *C. cyanus*, together with *C. officinalis* and *F. esculentum*, is included in a mix of annuals designed to give an available nectar and pollen for flower-visiting insects (Carreck, Williams 2002). Based on the results, the RDA analysis showed that in all 3 years there was a strong positive preference of beetles from the Coccinellidae to *C. cyanus*, despite the fact that each year the vegetation was arranged in different design. The presence of ladybeetles on *C. cyanus* was observed mainly in the early part of the season (Tables 2, 3). In this period, many flowers were still not open and ladybeetles were seen on the flower buds instead of on open flowers. This was most probably due to the extrafloral nectar which is produced by *C. cyanus* (Winkler et al. 2006). According to this author, extrafloral nectar can be an important source of carbohydrates for insects. The production of certain amounts of extrafloral nectar was also confirmed by the presence of ants foraging for nectar on the flower buds. As mentioned by Heil (2001), ants forage preferentially on the plants with extrafloral nectaries.

C. cyanus was recommended by Winkler (2005) as a plant visited by the hymenopteran parasitoid but not by the herbivores in the case of brassica crop. Some authors (Fitzgerald, Solomon 2004; Alomar et al. 2006) identified *C. cyanus* as an insectary plant that may be used to enhance predatory bugs (anthocorids) and hoverflies numbers. Syrphidae were seen on *C. cyanus* in greater amount only in the last year 2010. However, no predatory bugs (from genus *Orius* spp.) were found on this plant in the experiment.

From the research of Fiedler and Landis (2007), *A. graveolens* in late season and *F. esculentum* in midseason were evaluated as an attractive group for natural enemies. Hemiptera, Hymenoptera and Coleoptera were the most common or-

Table 4. Insect occurrence and flowering period in 2010

Species	Insect/Week	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	
Anethum graveolens	Syrphidae						11	13	20	20	29	11	3				
	Ichneumonidae								5	10							
	Coccinellidae	5	10	9	9	2		3	10	25	20	1					
	Orius spp.																
	main flowering period*						♣	♣	♣	♣	♣	♣	♣				
Calendula officinalis	Syrphidae				3	14	14	19	15	10	18	19	19	3			
	Ichneumonidae					1	1	1	3	8				2			
	Coccinellidae				10	3			2								
	Orius spp.								1	17	53	31	25	11			
	main flowering period*					♣	♣	♣	♣	♣	♣	♣	♣	♣			
Centaurea cyanus	Syrphidae					21	26	22	25		18	18	25	3			
	Ichneumonidae					1		4	3		1	1					
	Coccinellidae				9	4	11	2	18	24	22	46	26				
	Orius spp.																
	main flowering period*					♣	♣	♣	♣	♣	♣	♣	♣	♣			
Fagopyrum esculentum	Syrphidae	51	57	94	115	105	82	55	38	30	30	32	23	7			
	Ichneumonidae																
	Coccinellidae	3			15	22		1									
	Orius spp.																
	main flowering period*	♣	♣	♣	♣	♣	♣	♣	♣	♣							
Foeniculum vulgare	Syrphidae							20	16	19	16	24	36	30	38	5	2
	Ichneumonidae							4	3	8			14	10	2		
	Coccinellidae		7	15	5	12	8	2	9	13	2	7	18	23	16	29	33
	Orius spp.																
	main flowering period*										♣	♣	♣	♣	♣	♣	

*1/3 of flowers opened

ders of natural enemies collected in their research. Syrphidae and Ichneumonidae clearly preferred *A. graveolens* in 2008 and 2009. Winkler et al. (2006) considered *A. graveolens* very suitable for parasitoids. An advantage of this species is the presence of exposed nectaries which provide more concentrated nectar than the hidden nectaries. In our experiment this plant was visited mostly by hoverflies and parasitic ichneumon wasps.

In 2010, Syrphidae significantly preferred *F. esculentum*. This finding confirms the data collected by Ambrosino et al. (2006) who showed *F. esculentum* to be frequently visited by predatory hoverflies.

In 2010, Ichneumonidae still preferred *A. graveolens*, but a positive relationship was also found for *C. cyanus* and *F. vulgare*.

F. vulgare is a promising nectar or pollen source for ladybeetles, hoverflies and ichneumon wasps especially in the late period (Table 4).

Predatory bugs of *Orius* spp. have a significantly positive relationship with *C. officinalis*, which confirms the results from 2010. In previous years 2008 and 2009 the preference for *C. officinalis* was less expressive mainly due to the low incidence of this natural enemy.

Ladybeetle activity was noted on *V. faba* in the beginning of 2008 and 2009, but all of the ladybeetles were foraging on aphids rather than on flowers. In this case, *V. faba* can serve as an aphid reservoir for beneficial insects such as ladybeetle. Similarly, the before-flowering presence of Coccinellidae on *A. graveolens* and *F. vulgare* was also due to aphids foraging in these plants (Table 4). A similar idea has already been mentioned by Alomar et al. (2006), who stated that the co-occurrence of the predator and pest in flowers may also confer some potential for reducing pest populations and so prevent problems from developing.

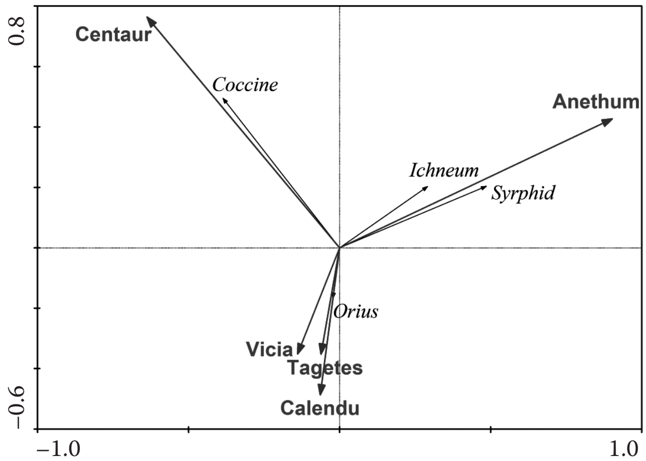

Fig. 2. RDA analysis for year 2009 (eigenvalues – 0.166, F – 8.947, P – 0.002**)

T. patula was visited only by a low amount of hoverflies in 2009.

Markedly more beneficial insect were observed during 2010 compared to 2008 and 2009 (Table 1). The main reason for this was the experiment design change. Besides this, some environmental factors would cause this change as well. The long term average yearly precipitation during the period from April till September is 325 mm in the location where the experiment took place (Tolasz et al. 2007). It was 269 mm in 2008, 297 mm in 2009 and 539 in 2010 (Mendeleum weather station). Experimental plots were irrigated, but vegetation in the close-by surrounding could suffer from water stress. Various authors (Miles et al. 1982; Studer 1994; McVean, Dixon 2001) found water stressed plants less favourable for aphids. Therefore those plants hosted lower aphid population in comparison to the non-stressed plants. It could be assumed, that during 2008 and 2009 populations of aphids were lower compared to 2010. Secondary, it could lead to the lower numbers of observed beneficial insects (Table 1).

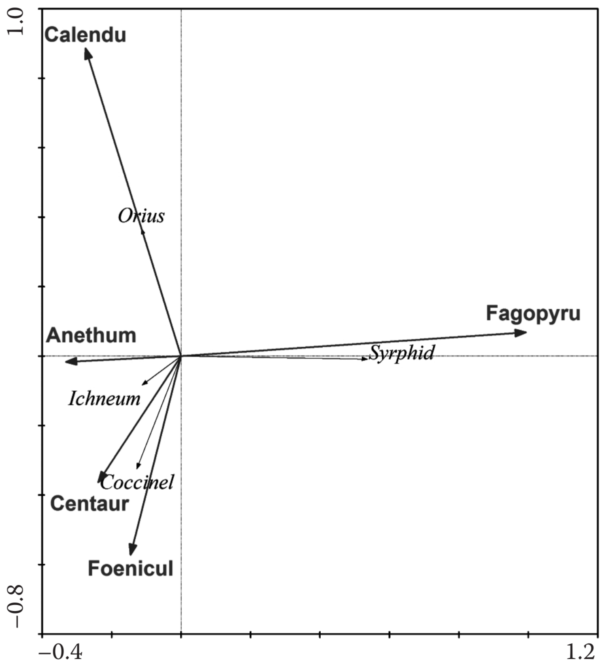

Fig. 3. RDA analysis for year 2010 (eigenvalues – 0.220, F – 125.701, P – 0.002**)

CONCLUSION

The quality and abundance of floral resources in time and space (i.e., nectar and pollen volumes, flower abundance, density, and dispersion) can affect the degree of selectivity among floral foragers (Thomson 1981; Waser et al. 1996) during the time and throughout the season. Therefore natural enemies show their preferences in the given circumstances (plant mixture, monoculture, different environmental conditions). *C. cyanus* (years 2008, 2009, 2010) and *F. vulgare* (year 2010) can be considered as an attractive source for ladybeetles (Coccinellidae). *F. vulgare* was also frequently visited by ichneumon wasps and hoverflies (year 2010). *A. graveolens* showed high visitation rates of hoverflies and ichneumon wasps (years 2008, 2009) and *C. officinalis* was visited by large amount of predatory bugs *Orius* spp. (2010). *F. esculentum* was significantly preferred by hoverflies (year 2010).

Therefore it could be concluded that *F. esculentum* (midseason), *A. graveolens, C. officinalis, C. cyanus* and *F. vulgare* (late season) could be recommended for creating flowering strips to increase these beneficial insect populations. The future research should be focused on the evaluation of the above mentioned flowering species on different pest population. It can be expected that especially the aphid population would be reduced by attracted beneficial insect. We would recommend to plant more (2–3) rows of one flowering plant species which will follow up (horizontally) with next rows of different plant species. Recommended design can meet both, the combination of all selected species and make flowering species more visible for natural enemies.

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